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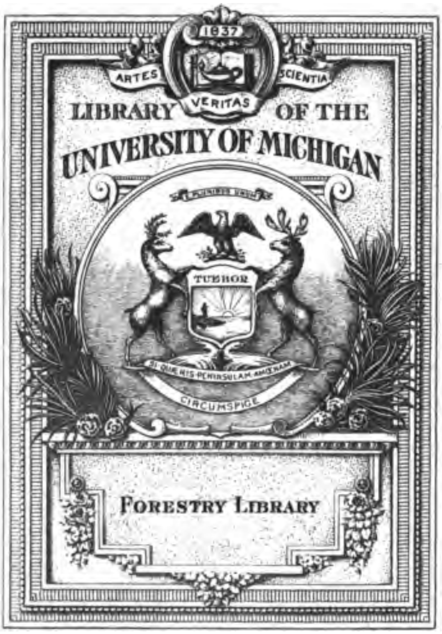

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN NO. 74.

L. O. HOWARD, Entomologist and Chief of Bureau.

No. 73 bound following 74

SOME FACTORS IN THE NATURAL CONTROL OF THE MEXICAN COTTON BOLL WEEVIL.

BY

W. E. HINDS, Ph. D.,
In Charge of Cotton Boll Weevil Laboratory.

Issued December 14, 1907.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1907.

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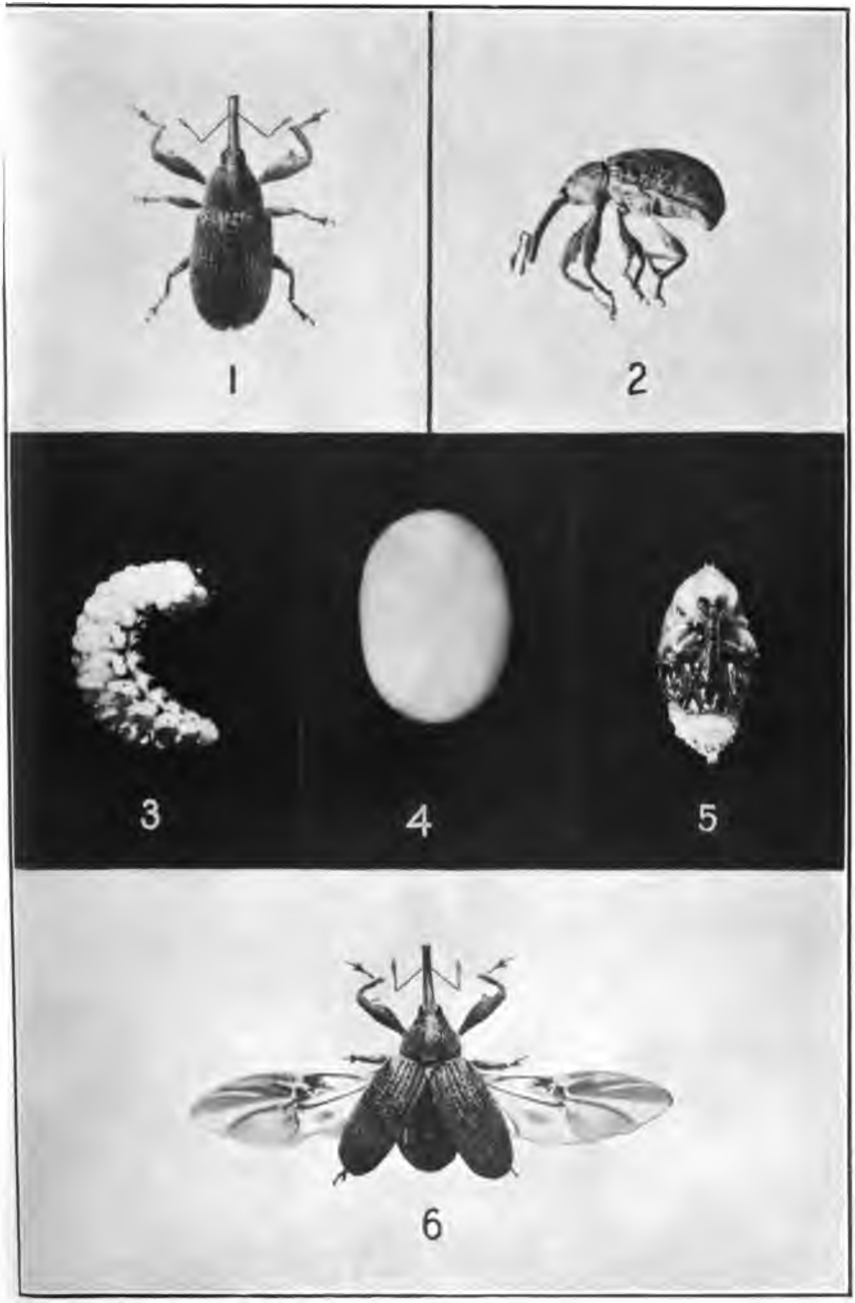

STAGES OF MEXICAN COTTON BOLL WEEVIL.

Fig. 1.—Adult weevil, dorsal view. Fig. 2.—Adult weevil, side view. Fig. 3.—Full grown larva, side view. Fig. 4.—Egg. Fig. 5.—Pupa, ventral view. Fig. 6.—Adult with wings spread. All except fig. 3 enlarged to 4 diameters; fig. 3 enlarged to 35 diameters. (Original.)

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., August 20, 1907.

Sir: I have the honor to transmit herewith the manuscript of a paper, by Dr. W. E. Hinds of this Bureau, entitled "Some Factors in the Natural Control of the Mexican Cotton Boll Weevil." It deals especially with three important factors of natural control, concerning which our knowledge has been largely extended through the cotton boll weevil investigations of the Bureau during the season of 1906. These factors are: Temperature and moisture conditions, predaceous and parasitic enemies, and food supply.

In view of the fact that the boll weevil is not a passing pest, but rather an enemy with which the cotton grower must reckon each year, it is evident that our knowledge of every factor affecting favorably or unfavorably its development and attack must be made as complete as possible. While it may not be possible to increase the effectiveness of some of these factors, there is reason to believe that with our more exact knowledge of the nature of their effect upon the weevil and of the conditions under which they produce most beneficial results others may be utilized far more than has been done heretofore, thus lessening very materially the damage annually inflicted by the weevil at little, if any, expense.

This study of the natural control of the boll weevil is probably based upon one of the most extensive series of definite examinations and records which has ever been made in economic entomology. The paper reporting this work is therefore based upon a large amount of statistical data. This has been tabulated with a view to as much condensation as possible without destroying the value and significance of the records. The illustrations accompanying the manuscript are necessary for the best understanding of the text. I recommend the publication of this report as Bulletin No. 74 of the Bureau of Entomology.

Respectfully,

F. H. Chittenden,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

In the earlier work of the cotton boll weevil investigation particular attention was given to the life history and habits of the boll weevil and the direct effect of these upon cotton production.

These phases of the investigation have been described in a number of circulars and bulletins of the Bureau of Entomology, among which the reader is referred especially to Bulletins 45 and 51, by Hunter and Hinds, and Bulletin 63, Part I, by Prof. E. D. Sanderson. The present bulletin deals especially with three factors of natural control in regard to which our knowledge has been largely extended by the work done during the season of 1906.

Those who are engaged in the cotton boll weevil investigations of the Bureau of Entomology are frequently asked if the boll weevil is not a passing pest, which may be expected in time to leave the cotton fields where it now occurs, because of a continuation of the onward movement by which it has spread through the great area which it now infests. This idea is doubtless based upon the fact that in any locality, in a series of seasons, there is likely to occur one season in which there will be a marked decrease in the abundance of the weevils. As a consequence of this an unusually good crop may be made, and after such a season with little weevil injury the planter is naturally inclined to anticipate that the weevil may never again become as serious a pest as it has been in the past.

The continuation of this investigation through a number of years has made it possible to determine that local variation, such as has been referred to, may be due directly to the influence of certain natural factors which, either singly or in combination, have exercised an unusually large degree of control upon the weevil. It has been possible to determine the most important factors concerned in this control and in some measure to show their relative importance. Extensive observations, however, have but confirmed the impression, which was formed years ago by entomologists engaged in studying this question, that the boll weevil is not a passing pest, but rather an enemy which must be taken into account every year by the grower of cotton throughout the infested area. With the certainty that the fight against the weevil must be continued indefinitely, it has become increasingly evident that our knowledge of every factor affecting, favorably or unfavorably, the development and attack of the boll weevil must be made as complete as is possible. While it may be impossible to increase the influence or effectiveness of some of these factors, there is excellent promise that it may be possible to utilize others to a far greater degree than has been done in the past, because of our more exact knowledge of the nature of their effect upon the weevil and of the conditions under which they produce most beneficial results. It is possible that by this greater utilization of natural forces the damage annually done by the weevil may be very materially decreased at little, if any, expense.

By "natural control" is meant the combined effect upon the weevil of all natural enemies and of all conditions or forces in nature which retard or prevent the development of the weevils and reduce the injury which they might otherwise inflict upon the crop. These are, in general, the factors which operate to produce and to preserve what is often spoken of as "the balance in nature." The principal factors are temperature and moisture conditions in summer and in winter, the attack of predaceous enemies or parasites, and the dependence of the species upon a favorable condition of food supply.

Since the beginning of the present cotton boll weevil investigations in 1901, the work in the field has been continuously under the direction of Mr. W. D. Hunter, to whom is due credit for many of the suggestions followed and for the breadth of scope which it has been possible to give to this particular portion of the investigation. Under his direction the work has been planned and carried out under the immediate supervision of the writer. Nearly all of the special field agents who have been in the investigation have had some part in the collection of material or in the examinations involved in securing the data for this bulletin. Special acknowledgment is due to them for the large amount of painstaking work without which this study could not have been made sufficiently extensive to have been of practical value. It gives the writer pleasure to acknowledge this indispensable assistance by Messrs. W. W. Yothers, R. A. Cushman, A. C. Morgan, C. R. Jones, W. D. Pierce, F. C. Pratt, F. C. Bishopp, W. H. Gilson, and J. C. Crawford.

W. E. H.

CONTENTS.

Page.

Introduction........ 11

Conditions requiring consideration........ 11

Influence of short drought in same season........ 12

Influence of a dry season upon succeeding season........ 14

Control by winter climatic conditions........ 15

Relationship of factors of control........ 19

Investigations showing control by heat, ants, and parasites........ 23

Natural control in various classes of forms........ 26

Desirability of retention or shedding of infested forms........ 31

Mortality in bolls versus squares........ 33

Natural control in various localities........ 35

Influence of climatic conditions especially........ 39

Influence of cultural conditions........ 43

Influence of period of infestation upon natural control........ 51

Efficiency of natural control in various sections........ 53

Mortality in each class of forms for each section........ 60

Sections profiting most by natural control........ 62

Destruction of cotton forms by weevil attack or by natural causes........ 64

  Collections of fallen forms in 1905........ 64

  Collections of fallen and of dried hanging forms in 1906........ 65

Summary and conclusions........ 73

Index........ 77

ILLUSTRATIONS.

PLATES.

Page.

PLATE I. Stages of Mexican cotton boll weevil. Fig. 1.—Adult weevil, dorsal view. Fig. 2.—Adult weevil, side view. Fig. 3.—Full-grown larva, side view. Fig. 4.—Egg. Fig. 5.—Pupa, ventral view. Fig. 6.—Adult with wings spread........................Frontispiece.

II. Stages and characteristics of *Solenopsis geminata*. Fig. 1.—Adult, small worker form. Fig. 2.—Sting of worker. Fig. 3.—Right antenna of worker. Fig. 4.—Adult workers, various sizes from workers minor to workers major. Fig. 5.—Larvæ and pupæ of small forms of worker. Fig. 6.—Larvæ of workers major compared with larva and pupa of small forms. Fig. 7.—Workers dragging off adult boll weevil which they have killed.................... 24

III. Signs determining boll weevil emergence or entrance of ant *Solenopsis geminata*. Fig. 1.—Emergence hole of boll weevil in cotton square. Fig. 2.—Entrance holes of ants in squares. Fig. 3.—Evidences of adult activity in square from which weevil emerged. Fig. 4.—Clean interior of square entered by ants. Fig. 5.—The three evidences of adult weevil activity, removed from square: *a*, Shed pupal skin; *b*, refuse formed in cutting emergence hole; *c*, excrement of unfed, young adult.................................. 26

IV. Shedding and retention of forms in cotton. Fig. 1.—*a*, *b*, *c*, Normal scars left by shed forms. Fig. 2.—*a*, *b*, *c*, Abnormal scars with forms retained. Fig. 3.—*a*, Longitudinal section through normal scar; *b*, longitudinal section through base of retained form......... 26

TEXT FIGURES.

FIG. 1. Map of Louisiana, showing dispersion movements of 1903 and 1904 and reduction of infested area by winter conditions of 1904-1905. 16

2. *Solenopsis geminata*.. 24

SOME FACTORS IN THE NATURAL CONTROL OF THE MEXICAN COTTON BOLL WEEVIL.

INTRODUCTION.

The natural control of the cotton boll weevil is so broad a subject, comprising the effects of so many factors, some of which are imperfectly known and understood, that anything like a comprehensive treatment of the subject is at present impossible. Doubtless many factors of some importance have not yet been studied. Of the fact that some factors do accomplish the destruction observed in individual cases we have no doubt. From extensive series of such observations we may be able to reason safely as to the general tendency of those factors, and we may possibly be able to assign to them a relative value in their tendency to control under the conditions then prevailing, but we must recognize the fact that all these factors, however many there may be, are so interrelated and their influences under varying conditions may so essentially differ that a study of them becomes an exceedingly difficult problem.

CONDITIONS REQUIRING CONSIDERATION.

The magnitude of the work involved is directly increased by the extent of the area affected and by the variations in climatic, geological, and cultural conditions which are encountered within the weevil-infested area. While some factors may be studied through multiplied observations as to their effect in individual cases, others must be considered from the broader standpoints of the general movement of the species, crop production, etc.

Temperature and moisture conditions are undoubtedly the principal climatic factors which govern in a general way the distribution of every species. Of these two factors, temperature is unquestionably the more important. The effect of this factor upon the continued spread of the boll weevil has been a subject of interest to entomologists ever since the weevil became a factor in the cultivation of cotton in Texas. It has been supposed that the weevil, coming originally from a habitat much farther south, would finally be checked by this temperature factor, and it was hoped that this would occur before the northern limit of profitable cotton production should be reached. Unfortunately, the insect has shown that it is capable of a considerable amount of adaptation to this change in temperature conditions, so that its northward range has been gradually extended until, in the season of 1906, it crossed the Red River Valley and became established in the southern portion of Indian Territory. Humidity has proved to be an important factor, affecting more the abundance and injuriousness of the species than it does its distribution.

Considering some of the broader aspects of the effect of temperature and humidity in controlling the weevil, it appears that the most marked instances of definite control have been occasioned by what may be termed the unusual variations, either above or below the usual range, in these factors. Thus it seems to be prolonged periods of extreme heat in summer and the exceptional depression in temperature in winter which have produced the most clearly marked results. When these exceptional conditions occur, they affect, as a rule, rather extensive areas, so that the good results are general instead of localized, as is likely to be the case with many of the factors which will be considered in succeeding pages. The possible effect of high summer temperatures has been the prime reason for recommendations designed to secure a proper spacing of the plants, which would leave weevil-infested squares most directly exposed to the sunshine. It frequently happens that this factor is sufficiently effective to so check severe weevil attack as to allow the cotton to set and to mature a reasonably good crop. It is especially effective if occurring early in the season during the period when the plant is normally setting its crop of fruit. Its value may be completely neutralized by other coincident or preceding conditions, such as a very rank growth of the plants, or a too close planting, which may cause the plants to shade a large proportion of the fallen forms.[a]

INFLUENCE OF SHORT DROUGHT IN SAME SEASON.

A definite illustration of the control of the weevil, largely by prolonged and excessive heat, was found at Victoria, Tex., in 1906. The plat of cotton under observation covered only one-half acre, so that it was possible to make frequent and close observations upon the conditions prevailing on the entire plat. Table I presents a brief summary of temperature, rainfall, crop, and weevil conditions for this area during a period of four months from the planting of the seed.

---

[a] The term "forms" is used for convenience to include all stages of the cotton fruit: The bud or square, the bloom or flower, and the boll or seed pod.

TABLE I.—*Temporary control of weevil by drought in May and June, Victoria, Tex., 1906.*

Month.	Temperature.				Precipitation.			Weevil and crop conditions.
	Absolute maximum.	Monthly mean maximum.	Monthly mean average.	Departure from normal.	Number of rainy days.	Total rainfall.	Departure from normal.	
1906.	°*F.*	°*F.*	°*F.*	°*F.*		*Inches.*	*Inches.*	
April..	87	79	70.3	−2.4	6	2.88	+0.22	Cotton planted early in month. Stand uneven.
May...	96	86	76.4	−1.6	2	.63	−3.29	Cotton began squaring about May 20. Weevils coming from hibernation in large numbers. No blooms, as all squares are destroyed as formed.
June...	103	94.3	83.7	+1.5	2	.68	−3.03	Weevils still coming from hibernation. No blooms until very last of month. First generation weevils nearly all destroyed while immature. Number of weevils in field greatly decreased by June 30. Blooms and bolls then forming abundantly.
July...	97	91.2	82.9	−1.3	12	4.93	+1.73	Weevils so checked by June conditions that before they could multiply again a good crop was set and a yield of about one-half bale was gathered in September and October.

It should be noted that in this field a considerable portion of the ground was exposed to sunshine through the unevenness of the stand. The rainfall during April was sufficient to give the plants a good start, and a fair growth was made through the month of May. April and May were somewhat cooler than is usual for those months. The weevils which had passed through hibernation in the vicinity of the field were so abundant early in the season that squares became infested as rapidly as they were formed. Squares began to form before May 1, but no blooms appeared, and conditions seemed to point to the inevitable failure of the crop until after the extreme heat and drought of June. During June the maximum temperature recorded was below 90° upon only one day, when it was 88° F. On three days the maximum temperature recorded was above 100° F. The mean maximum temperature for the month, 94.3°, is therefore exceptionally high. During the seventy-four days between April 20 and July 3 rains fell upon only four occasions and the total precipitation was less than $1\frac{1}{3}$ inches. This extreme heat and drought produced a very marked change in the weevil conditions found in this field. Through the gradual dying off of hibernated adult weevils and the long-continued destruction of their progeny, the number of weevils to be found in the field was very greatly reduced. Following the heavy and well distributed rains occurring in July, the plants quickly put out large numbers of squares, and before the weevils could multiply so as to do any considerable damage the plants had set a normally good crop of fruit. While weevils became numerous later in the season, a yield of nearly one-fourth of a bale was obtained from this half-acre plat.

The beneficial effect of this drought during the squaring season in Victoria County may be shown by a comparison of the yields for the seasons 1903 to 1906, inclusive. These figures as given by the Bureau of the Census in equivalent 500-pound bales are as follows:

Yields of cotton in Victoria County, Tex., 1903–1906.

Year.	Bales.
1903	5, 355
1904	6, 495
1905	9, 016
1906	16, 963

INFLUENCE OF A DRY SEASON UPON SUCCEEDING SEASON.

The duration of the dry period as related to the growing season of cotton determines primarily whether the beneficial effect shall be prolonged beyond one season. In the case cited at Victoria drought occurred only in the first third of the season, and its effect was upon the immediate crop, but the benefit would not be continued into the following year. In some of the dryer regions of cotton production it is not unusual to have an entire season covered by a period of comparative drought, and under such conditions the effect upon weevil abundance is quite different. Several illustrations of this have occurred in the region between Corpus Christi and San Antonio, Tex. One of the most definite instances is here given by way of illustration. In this case the effect was widespread, and may be judged by a comparison of rainfall, temperature, and crop conditions for Nueces County, Tex., during the years 1901–1904.

TABLE II.—*General illustration of drought control, Nueces County, Tex., 1901–1904.*

Year.	Rainfall.				Temperature.				Cotton production, Nueces County, equivalent 500-pound bales.
	Annual.		Mar. 1–Aug. 31.		Annual.		Mar. 1–Aug. 31.		
	Total.	Departure from normal.	Total.	Departure from normal.	Mean average.	Departure from normal.	Mean average.	Departure from normal.	
	Inches.	*Inches.*	*Inches.*	*Inches.*	°*F.*	°*F.*	°*F.*	°*F.*	
1901	17.49	−11.90	6.74	− 7.42	70.7	0.0	76.2	0.83	601
1902	22.22	− 7.98	5.57	− 7.39	71.5	+ 1.4	77.3	+1.85	480
1903	36.92	+ 6.72	25.97	+11.38	69.1	− 0.9	74.5	− 0.9	4,099
1904	28.54	− 1.66	13.56	+ 0.83	70.5	+ 0.4	76.0	+ 0.5	1,556

In connection with this table it should be noted that the temperature conditions during the six months which are of greatest significance varied but little from the normal. In rainfall, however, a great deficiency occurred both in 1901 and in 1902. Undoubtedly the continuance of the drought throughout the season was more influential than was the boll weevil in reducing the crop for the years 1901 and 1902, which were almost complete failures. Through the season of 1903 there fell a large excess of rain and it was well distributed. This would produce conditions very favorable for weevil multiplication and injury, but in spite of this the cotton crop for 1903 for this county was nearly ten times as large as during the preceding year. In 1904 both temperature and rainfall were nearly normal, but the effect of the large number of weevils passing through hibernation from the season of 1903 is very conspicuously shown by the reduced size of the crop of 1904. This is an illustration of the control of the boll weevil by the unfavorable climatic conditions of an entire season so effective that the weevil failed to become greatly injurious to the succeeding crop in a season when the climatic conditions were unusually favorable for its increase.

CONTROL BY WINTER CLIMATIC CONDITIONS.

Exceptionally low winter temperatures have occasionally proved sufficiently effective to exterminate the weevils from certain areas which had become recently infested and within which the weevils had not had time to become firmly established. This has been illustrated by several well established cases in northern Texas and Louisiana during the past few years.

Weevils were first found near Sherman, Tex., in the fall of 1903, when the northern limit of the dispersion reached to within a few miles of that place. No weevils could be found in that region in 1904 or until the dispersion of 1905 had taken place, thus proving that the few weevils reaching there in 1903 had failed to reproduce or that they and their progeny were completely exterminated by the winter conditions of 1903–4. Weather Bureau records show that the minimum temperature in this locality during the winter of 1903–1904 was 12° F. on January 26, 1904, and that the average monthly temperatures for January, February, and March at Sherman were +2.6°, +10°, and +6.9° above normal, respectively. It hardly seems probable, therefore, that the weevils failed to maintain themselves in this case solely on account of low winter temperatures.

Through the dispersion movements during the fall of 1904 weevils spread over a large area in western Louisiana, as shown on the accompanying map (fig. 1).

By a large number of very careful field examinations between May 1 and August 1, 1905, Mr. Wilmon Newell, entomologist of the Louisiana State crop pest commission, with the assistance of Messrs. E. S. Hardy, J. B. Garrett, W. O. Martin, and C. W. Flynn, working in cooperation with the boll weevil investigation of the Bureau of Entomology, was able to determine that the weevils had been practically, if not completely, exterminated in that portion of the 1904-infested area lying east of the heavy line shown in the map, running from the southwestern corner of Caddo Parish, through about the

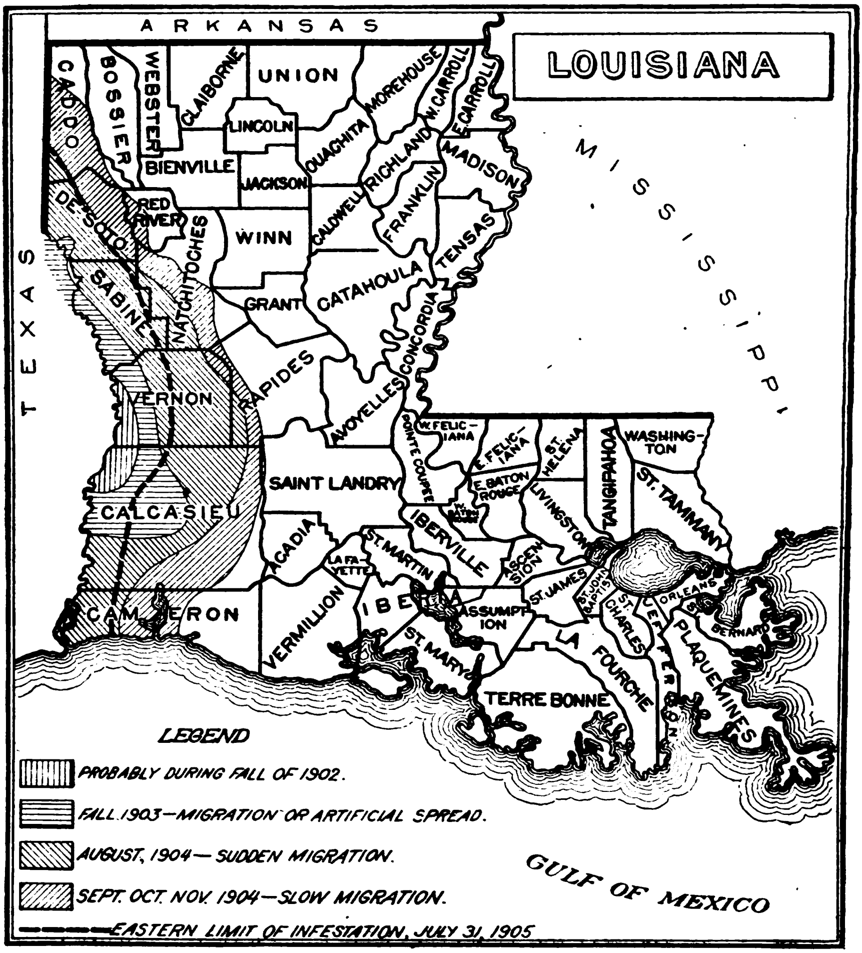

FIG. 1.—Map of Louisiana, showing dispersion movements of 1903 and 1904 and reduction of infested area by winter conditions of 1904–1905.

middle of De Soto, Sabine, and Vernon parishes and the western third of Calcasieu and Cameron parishes, nearly parallel to the western boundary of the State. In other words, through the unfavorable climatic conditions following the dispersion of 1904 the weevil was exterminated throughout practically two-thirds of the area in Louisiana which had first become infested by the weevil dispersion of that year. From the reports from Louisiana of the Weather Bureau for 1904 and 1905 it appears that killing frosts occurred generally through the State about November 13 to 15, 1904. The temperature and rainfall conditions within the infested area from that time till the end of December were not far from normal, though the rainfall during December was very heavy east of the infested area. During January the temperature in the infested area averaged about 5 degrees below the normal, while in February it reached an extreme departure, averaging 9 degrees below normal. During these two months the rainfall in this area was very heavy, averaging more than 10½ inches. Though this appears to be not more than 1 or 2 inches in excess of the normal rainfall during these two months, it is far more than the weevil has been obliged to withstand, as a usual occurrence, in Texas, and in conjunction with the very exceptionally low temperatures it probably explains in large measure the extermination of the weevils through practically all of the territory entered by them in the fall of 1904 after the latter part of August. It remains to be seen whether the heavy winter rainfall which normally occurs in this Louisiana territory will, as a usual thing, prove to be an important factor in reducing the number of weevils hibernating successfully within this area.

A somewhat similar reduction of infested area occurred in northern Texas coincident with that in Louisiana, but, owing to the demands of other lines of investigation in Texas, it was impracticable to make as thorough an investigation to determine the limit of infestation in July, 1905, in Texas as was done in Louisiana.

As the weevil seems to be acquiring a greater power of resistance to low temperatures as it spreads farther northward, the value of this factor for any locality now included within the weevil-infested area would seem to be gradually decreasing. The efficiency of winter cold is very largely affected by the coincident humidity and by the abundance and favorable character of the opportunities for shelter which may be obtained by the hibernating weevils.

Besides the direct effect upon weevil survival, winter climatic conditions exercise an indirect effect upon weevil injury during the following season by their influence upon the survival of cotton roots. This is an especially important consideration in southern Texas, where during many seasons a considerable proportion of old roots survive, giving rise in the spring to what is variously termed sprout, stubble, or seppa cotton. These sprouts arising from roots which are already established begin growing, as a rule, before cotton is planted. Their growth is exceptionally vigorous, so that these plants frequently produce squares several weeks in advance of the average planted crop. This source of food supply, occurring so early in the season, serves to sustain a large number of hibernated weevils from the time of their emergence until after the planted cotton becomes susceptible to their attack. It also furnishes early emerged weevils with opportunities for reproduction, which may produce a large number of first generation weevils by the time planted cotton begins to form squares. It has been noticed that during seasons when an exceptional amount of sprout cotton occurs weevil injury has, as a rule, been exceptionally severe. The increased injury during such seasons is undoubtedly traceable to two primary causes: (1) The climatic conditions which are most favorable to the survival of cotton roots are also as favorable to the survival of hibernating weevils; (2) the large numbers of weevils surviving under these conditions are provided with an abundant food supply and with early opportunities for reproduction by the sprout cotton which occurs.

During winters when the climatic conditions are unfavorable both for the survival of weevils and for the survival of old cotton roots the smaller number of weevils emerging in the spring find no other food supply than that provided by the planted cotton, and can not begin their reproductive activity until such time as the squares upon the planted cotton may be about one-half grown. Under these conditions the crop has a fair opportunity to set before weevils become sufficiently abundant to destroy a large proportion of the rapidly forming squares.

It is difficult to understand why so many planters fail to appreciate the importance of preventing entirely the appearance and growth of sprout cotton. The only way in which its occurrence may be positively prevented in all seasons and in all parts of the infested area is by the uprooting of the old plants. It is plain that the most effective time to do this, so far as securing a reduction in the number of weevils is concerned, is immediately following the maturity and picking of the crop. This prevents further multiplication of weevils at that time and removes the available food supply of those which are adult as long as may be possible before they can hibernate successfully. Extensive experiments and observations have shown that if the stalks be thoroughly destroyed (as by burning) from three to four weeks before the occurrence of the first frost in the fall and if the ground be kept clean, so that favorable opportunities for shelter are removed, the number of weevils surviving hibernation may be very greatly reduced. If by any chance sprout cotton appears in the spring, every plant of it should be destroyed to prevent its nourishing the weevils which may have survived. The practice of allowing sprout cotton to grow in a field of planted cotton can not be too strongly condemned. Certainly if planters could appreciate the fact that these occasional plants will, under usual conditions, enable the weevils to do much greater injury to the main crop, they would be very careful to destroy them. If planters in southern Texas fully appreciated the importance of this menace, there would soon be developed a strong public sentiment which would compel every planter to adopt methods which would prevent the occurrence of sprout cotton. It is entirely possible in a great majority of cases for the planter to insure for himself the beneficial effect of a large reduction in the number of weevils surviving hibernation, such as would result from occasional winters of unusual severity, even during seasons which would be favorable for the survival of large numbers of weevils. This, then, is the part of cultural practice which may be made to regularly supplement or possibly supplant the beneficial effects which are occasionally experienced by an exceptionally large degree of natural control through severe climatic conditions during the winter.

RELATIONSHIP OF FACTORS OF CONTROL.

It is evident that these factors, which are but the extreme fluctuations in climatic conditions, will only occasionally exert their maximum effect, and that under normal conditions of temperature and humidity other factors, having a more constant average efficiency, may surpass climatic variations in their controlling effect upon the weevil. It is to a study of some of these average factors that the present paper will be mainly devoted. Among the factors concerned in the natural control of the boll weevil in the United States to which especial attention has been given may be mentioned heat or drying, native ants, proliferation, parasites, the limitation of the weevil's food supply by the work of the cotton leaf-worm (*Alabama argillacea* Hbn.), and birds.

In this bulletin special consideration will be given to the effects of heat or drying, native ants, and parasites. Proliferation[a] was studied extensively in 1905, and the most important results of the investigation have been published.[a]

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[a] "Proliferation," as the term is used in connection with cotton, refers to a phenomenon which frequently follows the attack of weevils or other insects in cotton squares and bolls. It may be defined as the development of numerous elementary cells from parts of the bud or boll which are themselves normally the ultimate products of combinations of much more highly specialized cells. The resulting product is thus composed of comparatively large, thin-walled cells, which are placed so loosely together that the formation is of soft texture and has a granular appearance which may be seen with the naked eye. Proliferous formations lack the distinctive texture which is characteristic of the normal parts of either bud or boll. The consistency of the formation is soft and yielding, resembling somewhat a rather soft gelatin. From this apparent resemblance the term "gelatinization" is sometimes used instead of proliferation.

The work of parasites and the possibility of making them even more valuable in the fight against the weevil is considered fully by Mr. W. D. Pierce in another bulletin of this Bureau.[b] The relationship of birds to the boll weevil has been treated in several publications, principally by the Biological Survey.[c]

The study of the influence of the leaf worm upon weevil control will require at least another season before the results can be sufficiently complete for publication.

The work with proliferation was continued in 1906 only as far as seemed advisable to confirm preceding results and conclusions. It was found in 1905, in over 8,000 examinations, that proliferation produced an increase in weevil mortality, averaging, for squares and bolls together, about 12.5 per cent. From the data following in these pages it appears that there is an average mortality not attributable to heat or drying, ants, or parasites, among over 80,000 observations of squares and bolls together, averaging slightly over 12 per cent. The confirmation of previous conclusions is evident, but in reference to both it should be stated that the figures recorded must be considered as a conservative statement of the value of this factor, since it must be admitted that it may become effective in many cases even before the hatching of the weevil eggs and that it is practically impossible in a large series of examinations to determine whether an egg or very small larva of the weevil may have been destroyed. It must also be considered that proliferation resulting from feeding punctures of the weevil and of other insects frequently proceeds to such an extent as to itself accomplish a destruction of both squares and bolls entirely disproportionate to the severity of the feeding injury which originally incited the proliferation. The value of proliferation as a factor in controlling the weevil is therefore offset in some degree by its tendency to continue beyond the remedial point and by its abundant formation under certain conditions of irritation when no weevil stage is present.

The work with parasites has been sufficiently extensive to form a very reliable basis for further investigations which promise to give increasingly valuable results. The actual records of parasitism and the comparisons between this and other factors of natural control are given herewith, while the more special consideration of the conditions favoring parasite abundance, the biological study of the species found, and the possibility of increasing their effectiveness may be found as given by Mr. W. D. Pierce in Bulletin No. 73 of the Bureau of Entomology.

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[a] Bul. No. 59, Bureau of Entomology. (See p. 8 for bibliography of proliferation.)

[b] Bul. No. 73, Bureau of Entomology.

[c] Bul. No. 51, Bureau of Entomology, pp. 150–153; Buls. Nos. 22, 25, and 29, Biological Survey.

For many years the cotton leaf worm (*Alabama argillacea*) has been considered as an important cotton pest throughout the South, though the severity of its injury to the crop has been less during recent years than it was formerly. It now appears in destructive numbers only during the latter part of the season, usually after the crop begins to mature, and is not infrequently a welcome visitor. Especially in rank late cotton its destruction of the foliage enables light and air to penetrate more readily, thus preventing the decay of bolls lying on or near the ground and greatly facilitating the maturity of the crop. For this reason comparatively few planters now look upon the leaf worm as a pest to be controlled by the application of insecticides. Succeeding generations of the caterpillars remove an increasingly large proportion of the foliage until the plants may be finally stripped bare repeatedly before the close of the season.

The significance of the leaf worm in the control of the boll weevil rests directly upon its effect upon the food supply of the latter species. As the weevil has no other food plant than cotton, its final multiplication before the end of the season is usually limited directly by the abundance of squares and bolls within which it may breed. The defoliation of the cotton by the leaf worm stops immediately the formation of squares and the subsequent possibility of the setting of bolls. Further development of the weevils is thus abruptly checked. The maturing bolls may continue to give out weevils for some weeks, and previously infested squares may add to the number of adult weevils for from one to two weeks, but the sudden removal of the food supply and of the shelter usually enjoyed by the adults causes great mortality among them. Many weevils leave the bare fields in search of food, and thus, in various ways, the number of weevils in a field where the leaf worms work abundantly and thoroughly becomes very greatly reduced. If the leaf worms continue to strip the cotton until late in the fall there will be no possibility of an increase in the number of weevils. The leaf worms may actually accomplish what is practically a more or less complete early destruction of the cotton plants and a cleaning up of leaf rubbish in the field. Where this is the case it is safe to assume that so few weevils will survive or hibernate that a very positive benefit may be experienced during the following season, and if climatic conditions should favor the growth of cotton, a crop may be secured with comparatively little injury by the weevil.

Defoliation by the leaf worm may be especially effective if it should happen to be followed by winter climatic conditions which are exceptionally severe, so that only those weevils which found the most favorable hibernation shelter would naturally survive. The leaf worm does not, however, often occur abundantly during two successive seasons in Texas. Its work is often local and only partial in the field attacked. Frequently the plants leaf out and form squares after having been defoliated. It must, therefore, be placed rather low in the list of factors concerned in the natural control of the boll weevil.

It is possible that something can be done to increase the efficiency of this factor or to render it of more constant value, especially in such regions as the Red River valley of Louisiana, where the worm occurs with considerable regularity. It is evident, however, that the planter should not rely upon the leaf worm to secure the destruction of his stalks at as early a date as the picking of the crop may render possible. At present in the bulk of the infested territory it may be considered as an occasionally valuable factor, but the completeness of the control resulting from its occasional work is a most valuable demonstration of the effect which it is possible for the planter to secure quite regularly by himself destroying the food supply of the boll weevil early in the fall.

The irregularity of the leaf-worm attack makes it necessary that final conclusions as to its value in controlling the weevil be based upon observations extending over a number of years, but the data already collected show conclusively that with these two important pests of cotton present in abundance the leaf-worm work is a most positive benefit to the planter; and if it secures continuous defoliation until too late in the season for the weevil to resume its breeding, this may result in the practically complete control of the insect for the following season.

There can be no doubt that birds are an important factor in preventing the extraordinary multiplication of many species of insects. Considerable attention has been given to the determination of the value of various birds as destroyers of weevils, and this important work is being continued by the Biological Survey. These records show that birds do not yet constitute a very important factor in controlling the boll weevil. There are several reasons for this. The habits of the weevil are such that the adults are but slightly exposed to the attack of birds, except during the season of the fall dispersion.

In Cuba Mr. E. A. Schwarz has determined that a bird (*Icterus hypomelas*) has learned to tear open the fallen squares and eat the weevil stages infesting them, but in the United States no bird has yet acquired such a habit. The season at which birds capture most weevils is during the dispersion in the fall months, when the weevils are flying most abundantly. The destruction of a large number of weevils late in the season can not, however, be as effective in controlling the weevil as would be the capture of a comparatively few during the hibernation season or in early spring, but during the first half of the season very few birds frequent the cotton fields. For these reasons birds must be ranked low among the controlling factors, but it is possible that they will gradually acquire an increasing importance the longer the weevil remains abundant.

There are other factors which are, or may become, of relatively great importance in the fight against the weevil. Some of these have been but slightly investigated. It is safe to assume that the factors which have been mentioned include those which have thus far proved to be of greatest importance in holding the weevil in check to some extent.

The relative value of these factors is certain to change suddenly, and when one assumes a position of predominant influence the others must undergo a readjustment of relative position. It is certain that the efficiency of predaceous enemies and of parasites is gradually increasing, while it is probable that the gradual adaptation of the weevil to its new environment is rendering it more resistant, especially to the effects of the adverse climatic factors. Additional observations of the effects of these opposing tendencies should bring to light facts which will be of general significance in connection with the study of many other pests besides the boll weevil.

The area infested by the boll weevil in the United States now reaches a total of between 175,000 and 200,000 square miles. Of course but a small percentage of this enormous acreage is actually devoted to cotton culture, but the range in geological conditions is naturally great. Thus in Texas cotton is cultivated extensively on five or six very distinct geological areas each furnishing more or less distinctive conditions of environment affecting faunal, floral, and shelter conditions which may at any time prove to have an important significance in the weevil status.

INVESTIGATIONS SHOWING CONTROL BY HEAT, ANTS, AND PARASITES.

Observations of the effect of various natural factors in controlling the weevil have been accumulating since the beginning of the boll weevil investigation. The earlier records, however, were not made to include the simultaneous effect of several factors, and the records presented in this connection are therefore confined to the observations made during 1906.

Heat and drying are considered together, as their effects upon the immature weevil stages are coincident and inseparable. The efficiency of this factor naturally follows seasonal variations, but it is largely affected by the distance between rows, the size of the plants and density of their foliage, the season of occurrence in relation to the state of the cotton crop, and by cultural conditions.

Whenever ants are referred to in succeeding pages it should be understood that no reference is intended to the Guatemalan "kelep" (*Ectatomma tuberculatum* Oliv.), which has failed to maintain itself in Texas.

The native ants concerned in the control of the weevil are principally of the genus Solenopsis and varieties of the species *geminata* (fig. 2).

The principal points in the characterization of this species are as follows: There are two distinct nodes or scales in the slender petiole of the abdomen. All forms but the male have a sting (Pl. II, fig. 2). The antennæ (Pl. II, fig. 3) are ten-segmented; the club is formed of the last two segments, of which the terminal one is the longer. Maxillary and labial palpi have each two segments. The clypeus has two longitudinal ridges and the sting is very large. The color varies, but the workers usually seen are of a dark reddish brown, the color of the abdomen being often considerably darker than that of the head and thorax. Length of workers from 2 to 3 mm.

These ants form nests near the surface of the ground. All stages of development and forms of adults may be found in these nests practically throughout the summer season. The individuals which are most active, if not in fact those which are alone concerned in the attack upon the weevil, are the smaller workers which are commonly to be seen outside of the nests. In Plate II, figures 5 and 6, are shown some of the immature stages of this species. The queen larvæ are very much larger than the worker forms as is shown in the illustration. The pupæ are naked, and as they approach maturity the color gradually changes from a translucent white to a dark brown. The active worker form is shown in Plate II, figures 1 and 4.

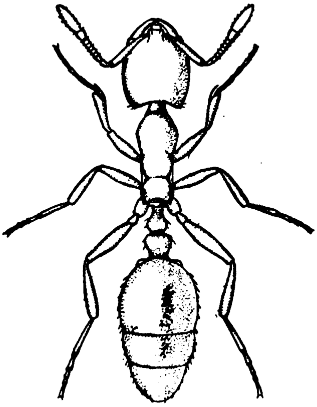
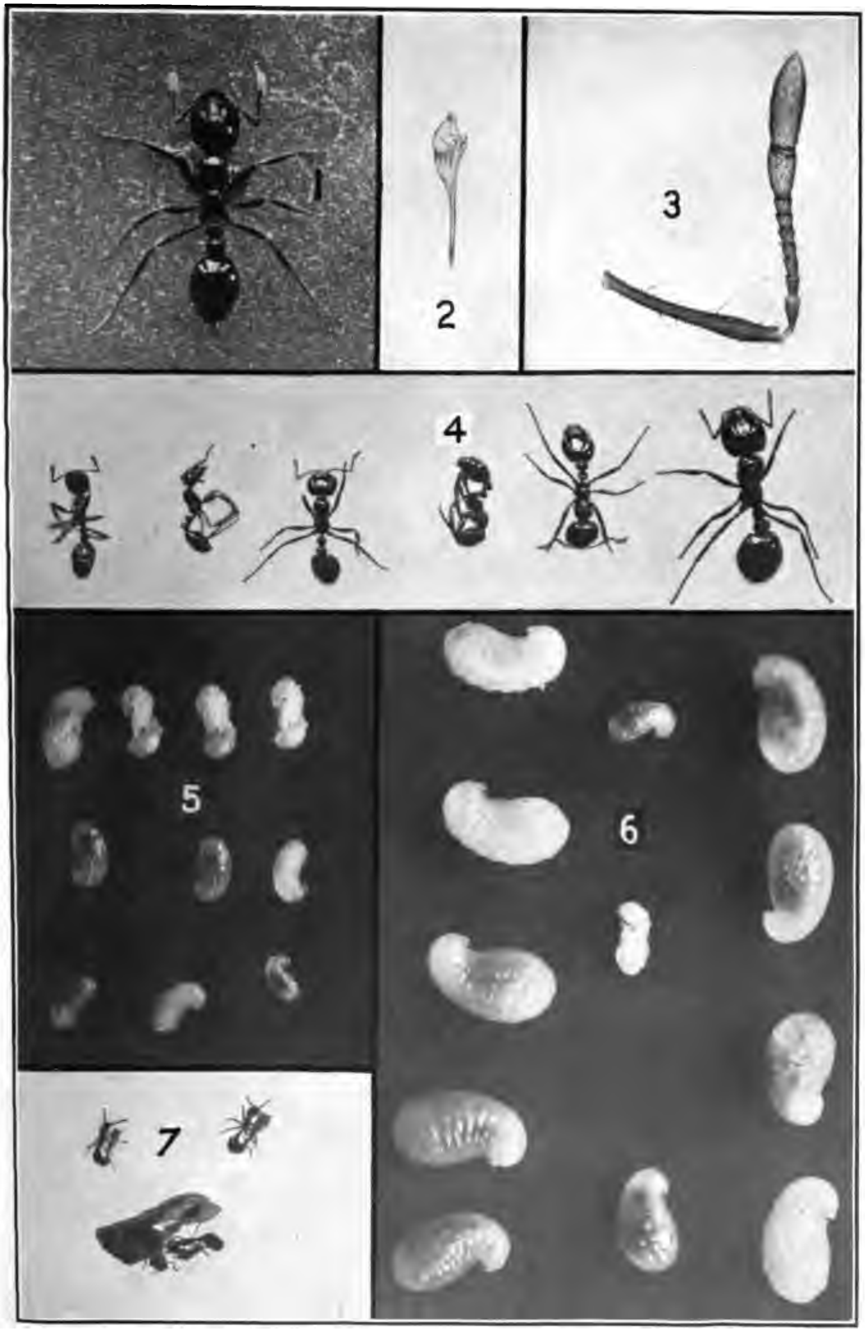


FIG. 2.—*Solenopsis geminata*, ant enemy of boll weevil. Much enlarged (from Hunter and Hinds).

This species shows a tendency to nest within the shade formed by the plants, and is to some extent out of the reach of ordinary cultivation by being close to the middle of the rows. The breaking up of a nest, however, does not seem to drive them away or to interfere seriously with their activities. In Plate III, figure 2, are shown cotton squares which have been entered by these ants and in which weevil stages have been destroyed. A comparison of the external resemblance of these entrance holes with the exit holes made by weevils is shown in Plate III, figures 1 and 2.

Since, in external appearance, the emergence holes made by adult weevils in escaping from squares resemble very closely the entrance holes made by the Solenopsis ants in obtaining access to the weevil stages in a square, it seems advisable to add a brief explanation of the manner in which these two classes of squares may be positively separated. In all cases the final determination as to the class in which a square belongs rests upon an examination of the interior. As



STAGES AND CHARACTERISTICS OF SOLENOPSIS GEMINATA.

Fig. 1.—Adult, small worker form. Fig. 2.—Sting of worker. Fig. 3.—Right antenna of worker. Fig. 4.—Adult workers, various sizes from workers minor to workers major. Fig. 5.—Larvæ and pupæ of small forms of worker. Fig. 6.—Larvæ of queens compared with larva and pupa of small forms. Fig. 7.—Workers dragging off adult boll weevil which they have killed. Fig. 1, enlarged to 7 diameters; figs. 2 and 3, to 40 diameters; figs. 4, 5, and 6, to 4 diameters; fig. 7, to 2 diameters. (Original.)

UNIV. OF MICH.

a general thing the emergence hole made by the weevil (Pl. III, fig. 1) is more regular in outline and somewhat larger in area than are the entrance holes made by the ants. Upon opening the square carefully it will be found that if a weevil has reached full development therein and emerged, there will be found present three definite signs which are not present in cases where ants have destroyed the weevil stage. One of these signs is the delicate white skin which is shed by a pupa when the weevil transforms from that stage to its adult condition. (Pl. III, fig. 5*a*.) This is usually so shriveled and twisted as to have no resemblance whatever to the outlines of a living pupa and is frequently more or less hidden in the débris which constitutes the second sign. This is a rather abundant mass of fine particles which have been torn from the square by the weevil in cutting its emergence hole. These are not eaten by the weevil but are left within its cell (Pl. III, figs. 3 and 5*b*). The third sign of adult activity consists of a number of particles of white excrement which are almost invariably deposited by the adult weevil before its emergence from the square (Pl. III, figs. 3 and 5*c*). These three signs are absent in cases where ants have entered and destroyed the weevil stages (Pl. III, fig. 4).

The value of a study based upon statistical data becomes easily apparent to one engaged in a thorough study of such a subject as this. Without it there is a strong probability that the general impressions formed may not give proper credit to the influence of the various factors. Conclusions which are based upon the total effects of the various factors in a large series of observations must necessarily be more reliable. This must be especially true of the general average of results from a considerable number of localities and under a considerable variety of geological and climatic conditions.

The first division in the data as obtained has been secured by separating the cotton fruit into several classes, each of which may contain weevil stages which have been exposed to similar conditions. But four of these divisions have been retained in the arrangement of the data shown in Table III. These are, (*a*) hanging, dried bolls; (*b*) hanging, dried squares; (*c*) fallen bolls; (*d*) fallen squares. As a rule infested squares and small bolls are shed by the plant in from seven to twelve days after the weevil attack. Many small bolls, especially, are shed normally, even though they may have suffered no injury from insect attack. This happens most commonly within a few days after the withering of the flower and before the young boll has made any growth. It may result from a failure in fertilization of the flower or the inability of the plant to sustain an excessive load of fruit. With both squares and small bolls, the shedding is accomplished naturally, just as is the shedding of leaves in the autumn, by the formation of an absciss layer of corky cells which cuts off the fibrovascular bundles through which the sap is supplied, thus destroying the vital connection between the bud or boll and the plant branch. The exact location of this cork area is shown by the scar left by a fallen leaf or square. It frequently happens, however, that for some reason the severance is incomplete and that the square or boll remains slightly attached to the plant though cut off as far as the vital connection is concerned (Pl. IV, figs. 2 and 3*b*). The difference in these two conditions may be seen and better understood by reference to Plate IV, figures 1 and 2.

The tendency to retain dead squares and bolls seems to be a characteristic of individual plants in nearly all varieties, but is most strongly marked in those which approach the limbless, cluster type of growth. In some fields the hanging, dried forms may be found very abundantly, while in others at the same time they may be very rare.

The retention of squares and bolls bears no definite relationship to the boll weevil injury, as many of the small bolls, especially, have never been attacked.

It is evident that the immature weevil stages in those forms which remain hanging upon the plant will be subjected to very different influences by the factors of natural control from those in fallen forms. This difference is especially marked as regards the exposure to the effect of sunshine and to the attacks of predaceous and parasitic enemies, and should be kept in mind in considering the data presented in the following tables.

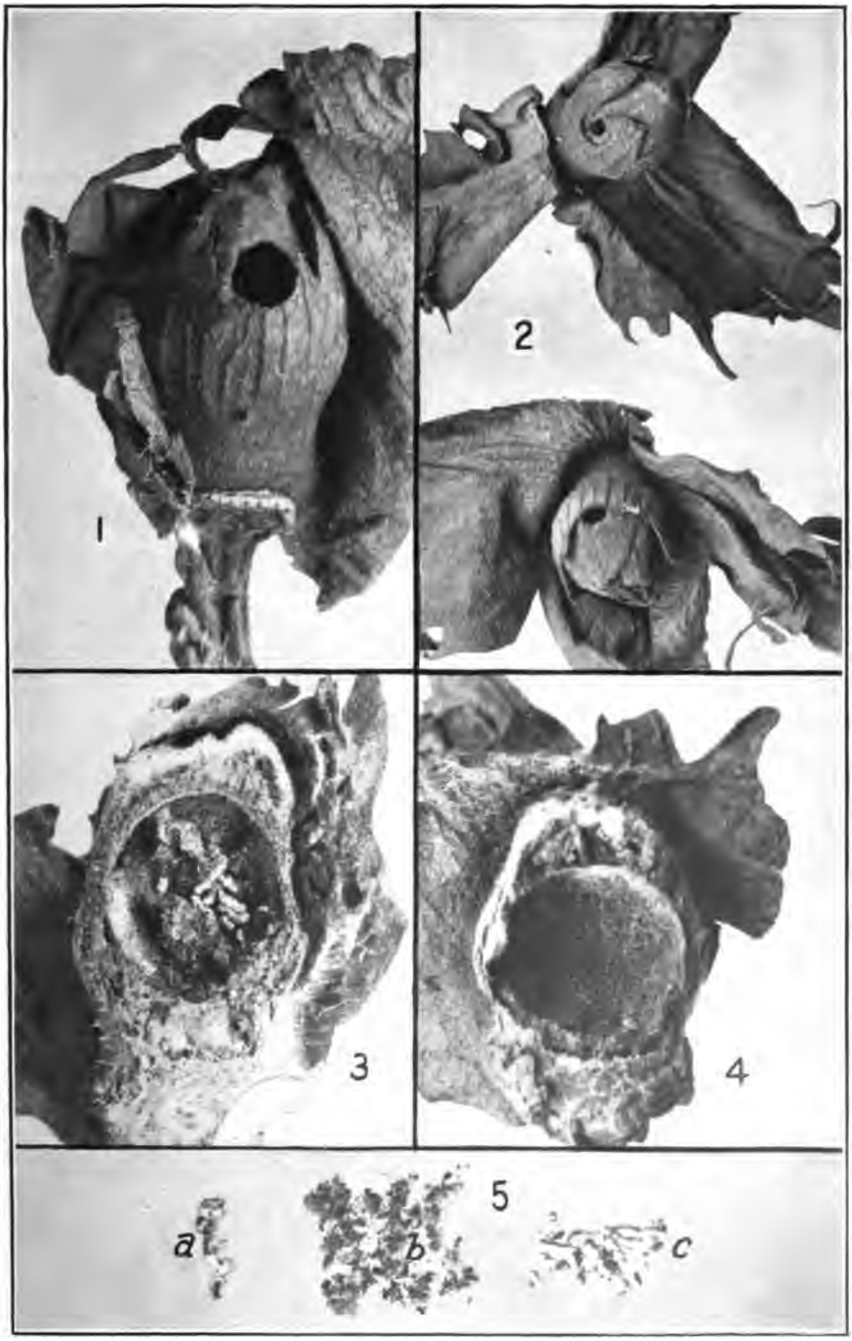
An explanation should also be given regarding the counting of stages. Besides each weevil stage, living or dead, which was actually found, one stage was counted for each case where there existed unquestionable evidence of its previous presence. This evidence would include the emergence hole made by an adult weevil, the cell within a square or boll from which some stage of the weevil had been removed by ants, and also the cases of parasitism. Since dead stages accumulate through a considerable period of time, or so long as the forms remain intact, and will be found and counted upon examination, it becomes necessary in determining percentages of mortality to count emergence holes as representing living adults which, of course, is really the case.

It would require too much space to give the detailed results of each of the examinations made. For each locality, therefore, all the observations made have been combined. This means in most cases that the figures given in these tables represent an average of several fields in each locality, and in seventeen of the twenty-eight localities where observations were made the figures combine the results of examinations upon from two to nine dates.

NATURAL CONTROL IN VARIOUS CLASSES OF FORMS.

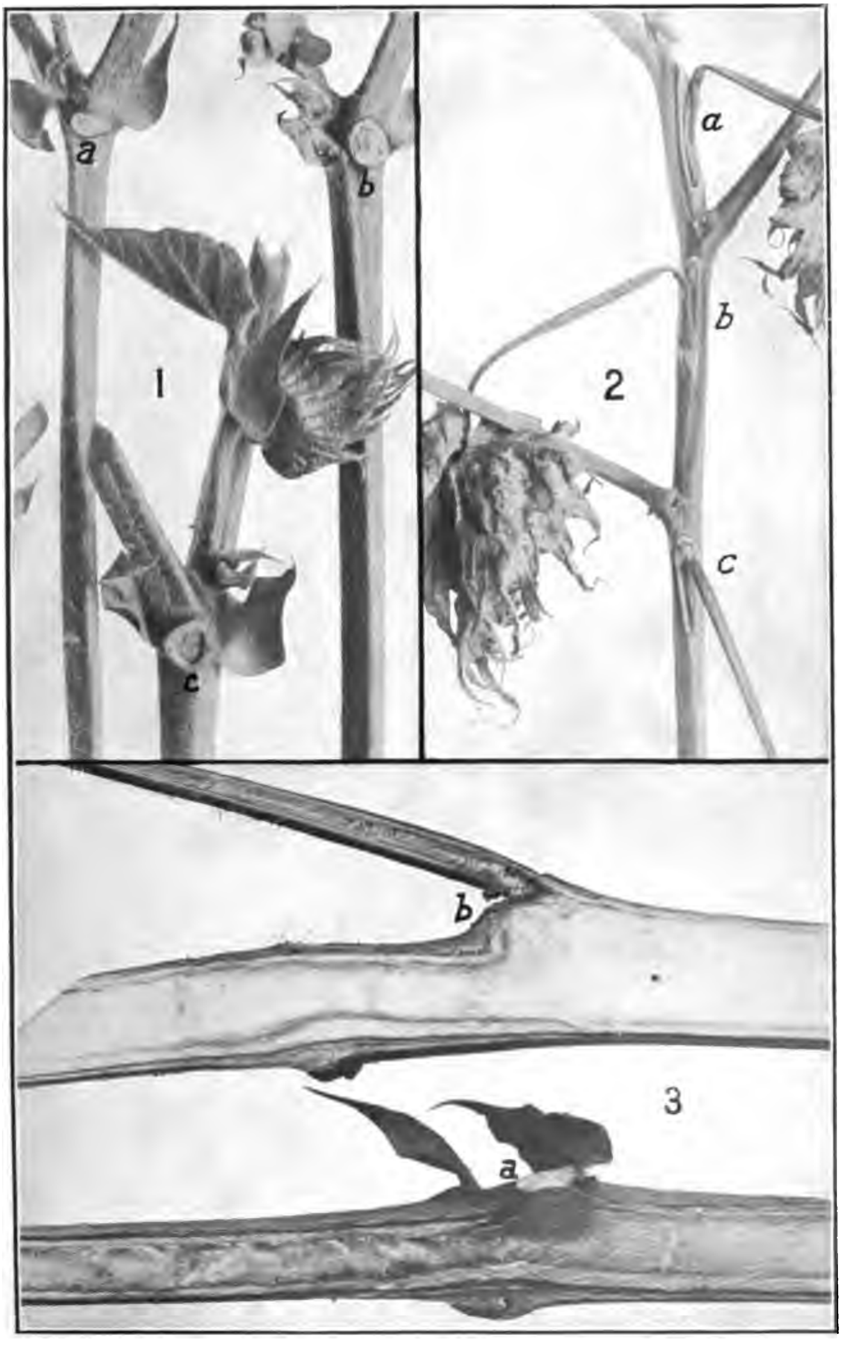
In collecting the forms for these examinations all were taken as they came, whether fallen, or dried and hanging to the plants. The green, growing forms were not examined.

Separate collections were made to secure hanging or fallen forms.



SIGNS DETERMINING BOLL WEEVIL EMERGENCE OR ENTRANCE OF ANT SOLENOPSIS GEMINATA.

Fig. 1.—Emergence hole of boll weevil in cotton square. Fig. 2.—Entrance holes of ants in squares. Fig. 3.—Evidences of adult activity in square from which weevil emerged. Fig. 4.—Clean interior of square entered by ants. Fig. 5.—The three evidences of adult weevil activity, removed from square: *a*, Shed pupal skin; *b*, refuse formed in cutting emergence hole; *c*, excrement of unfed, young adult. All, except fig. 2, enlarged to 4 diameters; fig. 2, enlarged to 2 diameters. (Original.)



SHEDDING AND RETENTION OF FORMS IN COTTON.

Fig. 1.—*a*, *b*, *c*, Normal scars left by shed forms. Fig. 2.—*a*, *b*, *c*, Abnormal scars with forms retained. Fig. 3.—*a*, Longitudinal section through normal scar; *b*, longitudinal section through base of retained form. Fig. 1, natural size; fig. 2, somewhat reduced; fig. 3, enlarged to 2 diameters. (Original.)

UNIV OF MICH.

TABLE III.—*Mortality of weevils.*

A. MORTALITY IN HANGING, DRIED BOLLS.

Locality.	Date.	Total number of forms examined.	Weevil stages alive.				Stages killed by heat or drying.			Evident cause of death.						Total weevil stages.		
					Adults.					Heat or drying.		Ants.		Parasites.				
			Larvæ.	Pupæ.	Present.	Emerged.	Larvae.	Pupæ.	Adults.	Number of stages.	Per cent of total stages.	Number of stages.	Per cent of total stages.	Number of stages.	Per cent of total stages.	Number found.	Number found dead from three causes.	Per cent of mortality from three causes.
Louisiana:	1906.																	
Mansfield	Sept. 24-29	1,705	38	47	77	112	18	19	22	59	9.4	199	31.9	37	6.0	624	295	47.3
Many	Aug. 23	1,250	43	103	84	117	25	21	32	78	14.5	53	10.0	32	6.0	539	163	30.2
Texas:																		
Calvert	Aug. 22-Sept. 13	901	17	35	41	23	17	2	1	20	11.5	25	13.8	12	6.6	181	57	31.5
Corsicana	Aug. 23	1,250	29	40	26	44	14	0	0	14	8.0	13	7.4	6	3.4	176	33	19.0
Cuero	Aug. 9-31	276	88	29	26	8	1	1	2	4	2.1	25	13.2	2	1.0	189	31	16.4
Dallas	Aug. 29-Oct. 15	4,604	144	243	239	255	38	11	18	67	4.9	232	17.0	67	4.9	1,362	366	27.0
Goliad	Aug. 7-Sept. 3	530	81	53	52	32	1	3	0	4	1.5	20	7.5	13	4.9	265	37	14.0
Hallettsville	Aug. 9-30	1,240	71	67	61	24	19	2	1	22	8.1	16	5.9	11	4.0	273	49	18.0
Marshall	Aug. 22	173	12	9	5	8	4	0	0	4	7.7	7	13.5	7	13.5	52	18	34.6
Overton	Aug. 23	210	9	15	8	10	4	2	1	7	7.8	32	36.0	4	4.5	89	43	48.3
Palestine	Aug. 10	510	77	46	23	27	6	0	0	6	2.8	8	3.8	7	3.3	211	21	10.0
San Antonio	Aug. 15	310	0	0	0	0	0	0	0	0	0.0	1	100.0	0	0.0	1	1	100.0
Taylor	Aug. 16	125	20	11	1	3	0	0	0	0	0.0	2	5.0	1	2.5	40	3	7.5
Trinity	Aug. 9-30	1,330	64	59	17	45	7	2	3	12	4.5	27	10.0	28	10.4	269	67	25.0
Victoria	Sept. 1	315	68	27	30	16	12	2	5	19	9.5	48	23.4	1	0.5	201	68	33.8
Waco	July 25-Oct. 12	2,630	55	72	137	268	70	8	32	110	11.4	194	20.1	94	9.8	961	398	41.4
Total		17,359	816	856	827	992	236	73	117	426	7.8	902	16.6	322	6.0	5,433	1,650	30.4

B. MORTALITY IN HANGING, DRIED SQUARES.

Louisiana:	1906.																	
Mansfield	Aug. 24	435	1	2	5	61	27	13	10	50	20.3	119	48.4	7	2.8	246	176	71.6
Many	Aug. 23	833	2	42	27	186	79	27	19	125	20.8	155	25.8	63	10.5	601	343	57.1
Texas:																		
Calvert	Aug. 22-Sept. 13	207	6	5	2	11	21	3	0	24	29.6	20	24.7	8	10.0	81	52	64.2
Corsicana	Aug. 23	125	4	9	7	12	18	2	2	22	25.9	19	22.4	12	14.1	85	53	74.1
Cuero	Aug. 9-31	931	97	60	40	16	85	4	1	90	20.6	32	7.3	87	20.0	438	209	48.0
Dallas	Aug. 29-Oct. 6	225	5	13	7	41	18	0	0	18	16.4	19	17.3	9	8.2	110	46	41.7
Goliad	Aug. 7-Sept. 3	337	7	25	20	59	14	3	2	19	9.1	48	23.0	29	13.9	209	96	46.0
Hallettsville	Aug. 9-30	602	16	45	80	53	38	8	9	55	13.8	110	27.6	37	9.3	399	202	50.6

TABLE III.—*Mortality of weevils*—Continued.

B. MORTALITY IN HANGING, DRIED SQUARES—Continued.

Locality.	Date.	Total number of forms examined.	Weevil stages alive.				Stages killed by heat or drying.			Evident cause of death.						Total weevil stages.		
			Larvæ.	Pupæ.	Adults.		Larvae.	Pupæ.	Adults.	Heat or drying.		Ants.		Parasites.		Number found.	Number found dead from three causes.	Per cent of mortality from three causes.
					Present.	Emerged.				Number of stages.	Per cent of total stages.	Number of stages.	Per cent of total stages.	Number of stages.	Per cent of total stages.			
Texas—Continued:	1906.																	
Overton	Aug. 23	56	1	0	1	8	1	0	0	1	2.2	33	73.3	1	2.2	45	35	77.8
Palestine	Aug. 10	468	24	94	56	57	51	11	5	67	17.2	37	9.5	48	12.3	390	152	40.0
Roosevelt	Sept. 25	216	20	19	5	10	6	1	0	7	8.6	18	22.2	2	2.5	81	27	33.3
San Antonio	Aug. 15	91	8	0	0	2	0	0	0	0	0.0	24	70.6	0	0.0	34	24	70.6
Taylor	Aug. 16	116	21	23	12	3	7	2	0	9	11.4	2	2.5	8	10.0	79	19	24.1
Trinity	Aug. 9–30	276	5	16	8	28	26	6	2	34	20.0	49	29.0	21	12.4	169	104	61.5
Victoria	July 2 and Sept. 1	1,158	119	161	69	83	140	10	8	158	19.7	111	12.6	82	10.2	802	351	31.3
Waco	July 25–Oct. 12	928	9	23	6	78	113	3	9	125	27.1	87	18.9	126	27.3	461	338	73.3
Total		7,004	345	537	345	708	644	93	67	804	19.0	883	20.9	540	12.8	4,230	2,227	52.6
C. MORTALITY IN FALLEN BOLLS.																		
Louisiana:	1906.																	
Mansfield	Aug. 24–Sept. 29	1,222	40	17	13	30	28	5	1	34	16.1	77	36.5	0	0.0	211	111	52.6
Many	Aug. 23	1,089	103	53	46	49	3	4	7	14	4.4	47	14.6	5	1.6	321	66	20.2
Orangeville	Aug. 23–Sept. 30	295	13	8	9	11	2	2	2	6	9.0	17	25.4	0	0.0	67	23	34.3
Texas:																		
Beeville	July 12 and Aug	2,116	75	33	26	22	60	7	4	71	22.0	92	28.4	0	0.0	324	163	50.3
Brownsville	July 28–Sept. 5	1,820	69	59	69	107	18	2	8	28	7.3	24	6.3	13	3.4	384	65	17.0
Calvert	Aug. 28–Sept. 13	913	203	113	9	2	2	1	0	3	0.9	4	1.2	0	0.0	347	7	2.0
Corpus Christi	July 10	321	8	8	2	1	1	0	0	1	5.0	0	0.0	0	0.0	20	1	5.0
Corsicana	Sept. 18	310	2	1	0	3	9	8	3	20	58.5	4	11.8	2	5.9	34	26	76.5
Cuero	Aug. 31	282	16	10	0	3	18	6	2	26	32.5	25	31.3	0	0.0	80	51	63.7
Dallas	Aug. 29	367	51	10	0	0	0	0	0	0	0.0	9	12.9	0	0.0	70	9	12.9
Fullers	Aug. 17	382	3	0	0	1	0	0	0	0	0.0	0	0.0	0	0.0	4	0	0.0
Goliad	Sept. 3	488	64	29	8	11	9	1	1	11	8.3	5	3.8	3	2.3	133	19	14.2
Hallettsville	Aug. 30	902	11	2	2	4	18	5	4	27	29.0	46	49.5	1	1.1	93	74	79.6
Junction	Sept. 24	44	5	2	0	1	3	0	0	3	17.6	5	29.4	1	6.0	17	9	53.0
Kerrville	Aug. 26–Sept. 3	500	215	41	10	2	9	0	0	9	3.1	7	1.4	7	1.4	295	23	7.8
Lula	Sept. 26	46	26	11	1	0	0	0	0	0	0.0	7	13.7	0	0.0	51	7	13.7

Marshall	Aug. 22	227	8	2	0	0	6	2	0	8	44.4	0	0.0	0	0.0	18	8	44.4
Mineola	Oct. 2	158	21	12	2	0	6	5	3	14	24.6	7	12.3	1	1.8	57	22	38.1
Overton	Aug. 23	375	29	9	5	0	4	0	0	4	4.4	44	48.4	0	0.0	91	48	52.7
Palestine	Aug. 10–Sept. 4	578	128	31	15	13	11	0	0	11	5.2	5	2.8	1	0.5	209	17	81.3
Roosevelt	Sept. 24	46	59	8	1	1	0	0	0	0	0.0	3	4.1	0	0.0	74	3	4.1
Taylor	Aug. 16	310	21	8	0	1	0	0	0	0	0.0	0	0.0	0	0.0	34	0	0.0
Terrell	Sept. 19	220	30	11	1	0	0	0	0	0	0.0	3	6.5	0	0.0	46	3	6.5
Trinity	Aug. 9–30	4,390	279	69	24	32	122	12	8	142	14.5	403	40.3	4	4.0	976	549	56.2
Victoria	June–Sept	2,351	171	53	6	3	17	9	0	26	9.2	19	6.8	0	0.0	281	45	16.0
Waco	July 25–Oct. 12	2,933	110	43	15	31	27	23	19	69	18.1	98	25.7	7	1.8	381	174	45.6
Total		22,685	1,760	643	264	328	373	92	62	527	11.4	951	20.6	45	1.0	4,618	1,523	33.0

D. MORTALITY IN FALLEN SQUARES.

Louisiana:	1906.																	
Johnsons Bayou	Aug. 22–27	300	106	80	19	17	0	1	0	1	0.4	1	0.4	0	0.0	225	2	0.9
Mansfield	Aug. 24–Sept. 29	962	36	31	12	104	46	18	6	70	14.6	218	45.3	2	1.2	481	290	61.1
Many	Aug. 23	2,008	105	218	48	325	60	16	6	82	6.6	479	37.9	5	0.4	1,367	566	44.7
Orangeville	Aug. 23–Sept. 30	900	89	71	25	58	5	2	0	7	1.6	161	37.0	5	1.1	435	173	42.1
Texas:																		
Beeville	July–Oct.	3,312	83	70	31	69	422	71	18	511	19.2	1,774	67.1	36	1.3	2,644	2,321	87.8
Brownsville	July 28–Sept. 9	7,142	105	423	321	439	989	145	49	1,183	38.2	380	12.3	194	6.3	3,095	1,757	56.8
Calvert	Aug. 28–Sept. 13	1,386	88	349	132	93	9	7	1	17	1.6	105	10.0	15	1.5	1,037	137	13.2
Corpus Christi	July 10	718	12	20	8	30	162	17	2	181	41.3	124	28.3	16	9.0	438	321	73.3
Corsicana	Sept. 18	26	1	0	0	1	3	1	0	4	25.0	10	62.5	0	0.0	16	14	72.5
Cuero	Aug. 31	1,550	13	18	8	17	455	110	12	577	54.7	340	32.1	11	2.4	1,059	928	87.6
Dallas	Aug. 29	111	14	8	0	7	2	0	0	2	3.6	23	42.6	0	0.0	54	25	46.2
Fullers	Aug. 17	100	20	0	0	1	0	0	0	0	0.0	0	0.0	0	0.0	21	0	0.0
Goliad	Sept. 3	1,305	65	74	52	90	166	68	7	241	29.4	198	24.1	70	8.5	821	509	60.8
Hallettsville	Aug. 30	1,380	18	15	1	17	380	76	12	468	44.0	474	45.6	5	4.8	1,040	947	91.1
Junction	Sept. 24	383	11	10	2	22	33	1	3	37	28.7	33	25.6	11	8.5	129	81	62.8
Kerrville	Aug. 26–Sept. 3	46	14	10	0	0	1	0	0	1	3.0	6	17.1	4	11.4	35	11	31.4
Lula	Sept. 26	278	22	12	6	3	2	0	0	2	3.6	3	5.6	0	0.0	54	5	0.9
Marshall	Aug. 22	52	7	4	1	0	3	0	1	4	17.4	7	30.4	0	0.0	23	11	47.6
Mineola	Aug. 10–Oct. 2	917	116	60	7	26	72	61	11	144	32.4	83	18.7	9	2.0	445	236	53.0
Overton	Aug. 23	312	5	6	0	2	11	4	1	16	8.1	166	84.3	2	1.0	197	184	93.3
Palestine	Aug. 10–Sept. 4	1,335	323	408	62	75	131	24	1	156	14.9	6	0.3	14	1.3	1,048	176	16.8
Roosevelt	Sept. 24	88	16	13	5	7	8	1	0	9	13.8	10	14.5	9	13.0	69	28	40.6
Taylor	Aug. 16	246	74	38	8	3	27	0	0	27	17.0	0	0.0	1	0.7	153	28	52.9
Terrell	Sept. 19	88	26	19	2	3	1	0	0	1	1.9	0	0.0	0	0.0	53	1	1.9
Trinity	Aug. 9 and 30	2,641	403	115	34	92	105	13	2	120	7.7	641	41.3	18	1.2	1,552	779	51.0
Victoria	June–Sept	8,004	1,054	384	121	303	1,787	53	8	1,848	28.5	2,010	31.0	200	3.1	6,488	4,058	52.5
Waco	July 25–Oct. 12	4,318	205	153	66	110	483	71	38	592	34.2	554	32.0	151	8.8	1,731	1,297	75.0
Total		39,908	3,031	2,609	971	1,914	5,363	760	178	6,301	25.6	7,806	31.7	778	3.2	24,710	14,885	60.5

From a study of the totals in each section of this table it appears that the highest average percentage of mortality from all three causes considered was found among the fallen squares, where it reached 60.5 per cent. The next highest average mortality occurred in the hanging, dried squares, with 52.6 per cent. The mortality in the two classes of bolls is very similar, with 33 and 30.4 per cent.

The data include only examinations of cotton forms which had been destroyed by some cause. In the majority of cases the destruction of the form could be attributed directly to weevil attack. The data upon this point are stated in subsequent tables. (See pp. 64–72.)

A comparison of the mortality records in hanging versus fallen forms (including both squares and bolls) shows that among the 9,663 stages found in hanging forms there was an average mortality of 40 per cent, while among the 29,328 stages in fallen forms there was an average mortality of 56 per cent. In hanging bolls the mortality is 30.4 per cent; in fallen bolls, 33 per cent; in hanging squares, 52.6 per cent; in fallen squares, 60 per cent. These figures show a consistent difference in favor of the fallen forms.

Parasites work more freely in the forms that remain attached to the plants than in those which fall to the ground, but in neither class of forms is their work as important as is that of the ants or even the effect of heat or drying. From many observations as to the stage of the parasite at the time of examination and from a general knowledge of the time that must have passed between it and the parasite attack, it appears that, as a rule, the parasite egg is deposited at about the time the square or boll withers. If this be the case, it is probable that the increased length of time during which the forms that remain attached and dry upon the plant are exposed to the parasite attack may explain the greater percentage of parasitization found in the hanging forms. In hanging forms parasitization amounts to 9 per cent, while among fallen forms it averages only 2.8 per cent.

The average total mortality among all classes of forms caused by the three factors was 52 per cent. As the weevil does not pass beyond the influence of these factors of control until after it has become adult and emerged from the square or boll, it is evident that among the 13,000 living stages found present there might still have occurred a very considerable mortality before all could have become adult and emergence taken place. The larval and pupal stages, which number over 80 per cent of all the living stages found present, are especially susceptible to the influence of the three natural factors of control under consideration. It would be very conservative to assume that fully one-half of the living stages present would have been destroyed had the forms been allowed to remain exposed to the influence of the factors of control until all surviving adults could have emerged. This would have increased the destruction of weevil stages by these factors to about 68 per cent.

DESIRABILITY OF RETENTION OR SHEDDING OF INFESTED FORMS.

Still another arrangement of general results may serve to show a comparison between the four classes of forms and between hanging and fallen forms. This arrangement is given in Table IV. It may serve to indicate for the entire infested area whatever general advantage there may be to the plant in the shedding or in the retention of its infested forms.

TABLE IV.—*Summary of mortality results shown in Table III, hanging and fallen forms.*

Class of fruit.	Total number of forms examined.	Total weevil stages found.	Weevil stages dead.		Cause of death.						Proportion of forms to each weevil stage.
					Heat or drying.		Ants.		Parasites.		
			Total number.	Per cent of total stages found.	Number of stages killed.	Per cent of total found.	Number of stages killed.	Per cent of total found.	Number of stages killed.	Per cent of total found.	
Hanging forms:											
Dried, hanging bolls........	17,359	5,433	1,650	30.4	426	7.8	902	16.6	322	6.0	3.20
Dried, hanging squares.....	7,004	4,230	2,227	52.6	804	19.0	883	20.9	540	12.8	1.66
Totals, hanging forms...	24,363	9,663	3,877	40.2	1,230	12.9	1,785	18.7	862	9.0	2.52
Fallen forms:											
Fallen bolls...	22,685	4,618	1,523	33.4	527	11.4	951	21.0	45	1.0	4.91
Fallen squares	39,908	24,710	14,885	60.8	6,201	24.7	7,806	32.8	778	3.3	1.62
Totals, fallen forms..	62,593	29,328	16,408	56.4	6,728	23.0	8,757	30.0	823	2.8	2.13
Summary of all forms:											
Hanging forms	24,363	9,663	3,877	40.2	1,230	12.9	1,785	18.7	862	9.0	2.52
Fallen forms..	62,593	29,328	16,408	56.4	6,728	23.0	8,757	30.0	823	2.8	2.13
Totals, all forms.....	86,956	38,991	20,285	52.3	7,958	20.5	10,542	27.2	1,685	4.3	2.23

The possibility of weevil damage having any relation to the retention of forms by the plant may be settled by a study of the proportion of weevil stages to each class of forms.

The last column of the table shows the average proportion of each class of forms to one weevil stage found. It must be borne in mind that many squares and bolls are destroyed by the feeding of the weevils in which no eggs have been deposited. Undoubtedly in a great many cases a young larva may have died when no trace of its presence could be found at the time the examination was made. This would especially apply to the hanging forms. From the proportions given it appears that, among hanging forms, twice as many bolls were examined for each weevil stage found as in the case of squares, while among fallen forms the proportion is three to one. This indicates that there is practically no difference in the proportion of weevil stages to squares, whether hanging or fallen, but that there is a natural tendency on the part of the plant to shed a large number of uninfested bolls soon after their formation and before weevil attack has taken place. Many of the dried hanging bolls also fail to show any sign of weevil attack. The attack of the weevils upon squares is, therefore, of much greater importance in their multiplication than is their attack upon bolls. Here again the importance of natural control is shown by the mortality in all squares, amounting to almost 60 per cent, whereas in all bolls it was but 31.6 per cent.

These figures show a remarkable similarity in the degree of infestation for the corresponding classes of fruit. This agreement is so close as to lead to the conclusion that the attack of the weevil has practically no effect upon the tendency of the plant to retain a portion of its surplus fruit in this way.

The proportion of hanging to fallen forms is not accurately shown by the figures given here as no effort was made to collect the hanging and fallen forms from the same areas at each examination made. This proportion varies very greatly in different fields and during different periods of the season, but it is safe to say that in the examinations recorded a much larger proportion of hanging, dried forms was collected than would be found in any ordinary field of cotton, unless it were of some limbless variety, such as the Dickson. Among the forms examined, nearly 70 per cent of the squares and bolls had fallen. These fallen forms contained somewhat more than 70 per cent of all the weevil stages found. The proportion of weevil stages to forms is very closely similar in hanging and in fallen forms, but the percentage of mortality in hanging forms averages 40, while in the fallen forms it averages over 56 per cent. The relative importance of the mortality in the two classes of forms as related to the whole question of natural control is shown to a fair degree by a comparison of the percentages of mortality in hanging versus fallen forms, based upon the total number of stages found in the total number of forms examined. In this way we find that among the 38,891 weevil stages found the 3,877 dead in hanging forms constitute approximately 10 per cent, while the 16,408 dead in fallen forms constitute 42.1 per cent. Since, as has been stated, the hanging forms examined are in a greater proportion to the fallen forms than actually occurs in the average field, it follows that it is conservative to say that, as a rule, the total mortality in fallen forms will average to be, at least, four times as great as that occurring in the hanging forms. Consequently the factors of natural control which affect especially the weevil stages in the fallen forms must be given a correspondingly high rank as compared with those which affect more especially the stages in the hanging forms. Figuring in this way for each of the three factors of natural control given, we find that heat or drying caused a mortality of 3.2 per cent in hanging forms and 17.5 per cent among fallen forms, ants caused a mortality of 4.6 per cent among hanging forms and 22.4 per cent among fallen forms, while parasites caused a mortality of 2.2 per cent among hanging forms and only 2.1 per cent among fallen forms.

The conclusions may also be drawn from a study of the proportion of weevil stages found dead in each class of forms, in connection with the factors causing death and the proportion of forms to weevil stages in each class examined. In this way it appears that the lowest total mortality was found in the hanging bolls which dried upon the plant, being in this case 30.4 per cent. For fallen bolls this percentage was 33.4, in hanging squares there was a mortality of 52.6, while in fallen squares it amounted to 60.8 per cent. Taking next a comparison of hanging and fallen forms, it appears that there was an advantage during the season of 1906 of 16.2 per cent greater total mortality among the fallen forms.

As to the factors which were most effective in producing this mortality, it appears that among hanging forms ants produced 46.5 per cent of the total mortality found, while in fallen forms they were responsible for 53.2 per cent of the total mortality. It is evident, therefore, that in either hanging or fallen forms *Solenopsis geminata* was the most important summer factor in 1906 in controlling the weevil. When it is considered that a large majority of the infested forms fall, it becomes still more certain that the effectiveness of the factors naturally tending to control weevil multiplication is greater when the infested forms are shed than when they are retained by the plant.

From these data it appears that it is more desirable that plants shed their infested forms completely and quickly after the infestation takes place than that they should retain them, allowing the weevil stages therein to develop under the smaller influence of natural control to which they would then be subjected.

MORTALITY IN BOLLS VERSUS SQUARES.

It should be stated that in these examinations no attempt was made to determine the mortality among weevil stages in large bolls which continued their development in spite of the weevil attack. In such bolls it is obvious that heat or drying can have had little if any effect upon the weevil stages. Ants do not enter green, growing bolls, though they frequently destroy weevil stages which become more easily exposed to their attack through the opening of the bolls. Instances have been found of parasitism of weevil stages in large bolls. Proliferation is, however, an active factor which has been found in the examination of more than 12,000 locks to produce an increase in mortality of weevil stages amounting to between 6 and 7 per cent.

For this comparison the figures given in Table III are combined for bolls and for squares.

TABLE V.—*Mortality in bolls versus squares.*

	Total forms examined.	Total weevil stages found.	Per cent of stages alive.	Per cent of mortality caused by—			Per cent of total mortality, three factors.
				Heat.	Ants.	Parasites.	
Bolls	40,044	10,051	64.5	9.5	18.4	3.6	31.6
Squares	46,912	28,940	36.1	24.5	30.0	4.6	59.1

Several general conclusions may be drawn from the study of these figures. In bolls nearly two-thirds of all the stages found were alive, while in squares the living stages constituted but slightly more than one-third of the total stages found. Heat is about two and two-thirds times as effective against the weevil stages in squares as against those in bolls. Ants are also much more effective in raising the mortality in squares. Parasites are slightly more active in attacking weevil stages in squares than in bolls, but the difference in this case is much less than in the case of ants or heat. From the combined effect of these three factors there is a total mortality averaging in bolls a little less than one-third, and in squares nearly three-fifths, of all weevil stages present.

Among the 38,991 weevil stages found, 63.5 per cent of this total number occurred in fallen squares. It is evident, therefore, that the factors of natural control which are most effective in destroying weevil stages in fallen squares are the most important in restricting the summer multiplication of the weevil. It appears that the Solenopsis ants and heat are the two most important factors in this connection.

In these examinations it was impossible to account for eggs and very small larvæ, as the drying of much of the material and the decay present in another large portion would inevitably efface all traces of these stages even in cases where the work of the living larvæ was not sufficient to have done so. In the absence of positive data showing the mortality in these young stages, no attempt will be made to estimate the mortality that undoubtedly does occur early in the weevil's development. It is certain that the average of the smallest larvæ found would not be more than one-third or possibly one-fourth grown, but the data given for the stages above the one-third grown larva are thoroughly reliable.

It is therefore safe to say that the mortality of the boll weevil throughout the infested area, as represented by twenty-eight well-distributed localities, during the period from June 16 to October 15, 1906, from the effects of heat or drying, ant, and parasite attack averaged not less than 65 or 70 per cent of all the weevil stages surviving beyond six or seven days from the deposition of the eggs. If to this percentage we add the 12 per cent which were found dead from some cause other than the three under consideration, but principally due to proliferation, we have a total mortality of from 75 to 80 per cent.

The average length of the developmental period from June to October is shown in Bulletin 51, Bureau of Entomology, page 94, to be between eighteen and twenty days. The mortality shown by these records occurs, therefore, during the last two-thirds of the period between the deposition of the egg and the emergence of the adult weevil. When it is considered that a considerable proportion of eggs and very young larvæ must also be destroyed, it becomes increasingly apparent that but a very small percentage of the total number of eggs deposited by the weevils in a field of cotton produce adults.

It may seem that this tremendous destruction of weevil stages would be sufficient to bring the weevils under practical control so that the comparatively small remainder would produce little injury to the crop. Such, however, is not the case. The fact is that in nearly if not quite all of the fields examined the weevils were so abundant as to destroy a large portion of the crop, and in most cases it is probably true that the multiplication of the weevils was finally limited by the amount of food supply present rather than by the destruction of the weevil stages by all these factors of natural control. This does not mean that the crop did not benefit by the destruction of weevil stages accomplished, for had it not been for this checking of the possible multiplication of the weevils few of the fields could have produced a crop that would have been worth the picking.

Were it not for the fact that in nearly all cases the destruction of the weevil stage occurs only after the weevil has destroyed the cotton form, the crop might be much more largely benefited by this natural control. Without the natural control existing, cotton production within the weevil-infested area would be impossible; with it alone, the continuance of cotton culture may still be possible; but only by supplementing the work of nature by the most practicable methods known can the balance be thrown largely in favor of the planter in producing a very profitable crop.

NATURAL CONTROL IN VARIOUS LOCALITIES.

In the sections of Table III the data are divided according to the class of forms examined in order to make apparent the varying differences in the effects of the several factors of natural control upon the weevil stages in each class of forms. In studying the combined effect, which is really the measure of control in any locality and for any period of time, this separation into classes is no longer necessary. For this reason the figures given in Table VI represent a combination of the four classes given in Table III. It is proposed to show for each locality the proportion of the total mortality due to each of the three factors, a comparison of the mortality in each stage of the weevil—larva, pupa, and adult—and the general climatic conditions prevailing during the period covered by the examinations. In this way it may be possible to show whether any particular combination of climatic conditions prevailed in coincidence with the highest percentages of mortality found, or whether the percentages may vary widely under similar climatic conditions so that the real explanation for the variation must be due to other causes than climatic differences. In this table, as in Table III, the percentage of mortality in *larval*, *pupal*, and *adult* stages is based upon the total numbers of those stages which were found alive or which had died from the effects of heat or drying. It seemed impracticable to attempt the determination of the stage of the weevil destroyed by ants and parasites, though in many cases it would have been possible. The "total of weevil stages found" includes those found alive, those killed by heat or drying, and those which had died but probably from some other cause than heat, and each weevil cell emptied by ants as well as each instance of parasite occurrence.

In the column showing "total mortality from three causes" it may be seen that the range is from 0 to 84 per cent, with the average at 52 per cent. Eleven localities show a mortality above the average and seventeen below it. For the eleven the average mortality is 63.2 per cent, while for the seventeen the average is but 34.2 per cent. It is noticeable that nearly all of those showing the higher percentages are located below or south of the center of cotton culture in Texas. The figures in Table VI show the conditions for mortality by these three factors, and also give in each locality and in a general way the climatic conditions prevailing during the period of examination and for ten or fifteen days previously. In cases where no records are available, those are used for a near-by locality having weather conditions probably similar to those of the locality in which the examinations were made. The totals in this table show the general facts concerning mortality under average conditions in the twenty-eight localities representing in a general way the infested area. Besides the comparison as to mortality by each of the three factors represented there is a general record showing the mortality found in each stage of the weevil from heat or drying. The records of the four principal classes of forms examined are combined in this table.

It is shown that the mortality from heat in the larval stage amounts to 52.6 per cent, in the pupal stage to 18 per cent, and in the adult stage to 6.3 per cent. Nearly 70 per cent of all the mortality caused by heat or drying occurs, therefore, during the larval stage. An early shedding of infested forms is plainly very desirable.

TABLE VI.—*Comparison of mortality records from heat or drying, ants, and parasites for Louisiana and Texas in 1906.*

Locality.	Date or period.	Total of four classes of forms examined.	Total weevil stages found.[a]	Total stages killed by heat, ants, and parasites.	Total mortality from three causes.	Percentage of mortality from—			Mortality from heat or drying[b] among weevil stages.						Climatic conditions.[c]						
									Larva.		Pupa.		Adult.			Temperature.			Rainfall.		
						Heat or drying.	Ants.	Parasites.	Number of this stage found.	Per cent of this stage dead.	Number of this stage found.	Per cent of this stage dead.	Number of this stage found.	Per cent of this stage dead.	Period included.	Mean maximum.	Mean average.	Departure from normal.	Total rainfall.	Departure from normal.	Number rainy days.
Louisiana:	1906.				*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*		*P. ct.*		*P. ct.*		*P. ct.*	1906.	°F.	°F.	°F.	*In.*	*In.*	
Johnsons Bayou	Aug. 22-27	300	225	2	0.9	0.4	0.4	0.0	106	0.0	81	1.2	36	0.0	......	......	......	......	......	......	......
Mansfield	Aug. 24-Sept. 29	4,324	1,562	872	56.1	13.6	39.2	3.2	234	50.1	152	36.2	453	8.6	Aug. 1-Sept. 30	89.7	78.9	+ 1.5	7.37	......	16
Many	Aug. 23	5,180	2,828	1,138	40.2	11.0	26.9	4.0	420	40.0	484	14.0	946	7.0	Aug. 1-31	92.9	80.6	......	0.58	−2.79	2
Orangeville	Aug. 23-Sept. 10	1,195	502	196	39.4	2.6	35.5	1.0	109	6.4	83	4.8	105	2.0	Aug. 1-Sept. 30	89.4	80.2	+ 2.0	6.01	−1.31	9
Texas:																					
Beeville	July 12-Oct. 1	5,428	2,968	2,484	84.0	20.0	62.8	1.2	640	75.3	181	43.1	170	12.9	July 1-Aug. 31	94.2	83.8	−1.35	5.49	+1.42	12
Brownsville	July 28-Sept. 5	8,962	3,479	1,822	52.5	34.8	11.6	6.0	1,181	85.3	629	23.7	993	5.7	July 1-Aug. 31	92.2	84.1	+0.9	8.83	+3.88	12
Calvert	Aug. 22-Sept. 13	3,407	1,646	253	15.1	3.9	9.3	2.1	363	13.5	515	2.5	315	0.6	Aug. 1-Sept. 30	94.6	83.7	+1.5	10.22	+6.10	25
Corpus Christi	July 10	1,039	458	322	70.3	40.0	27.1	3.5	183	88.0	45	37.7	43	2.3	July 1-31	88.8	83.0	+1.3	0.41	−0.91	3
Corsicana	Aug. 23-Sept. 18	1,711	311	126	40.5	19.3	14.8	4.5	80	55.0	61	18.2	98	5.1	Sept. 1-30	90.9	79.7	+1.6	2.53	−0.71	7
Cuero	Aug. 9-31	3,039	1,766	1,219	69.0	39.5	23.9	5.7	773	72.3	238	50.9	135	12.6	Aug. 1-31	94.5	83.8	−1.0	2.43	+0.77	4
Dallas	Aug. 29-Oct. 15	5,307	1,596	446	28.0	5.5	17.7	4.7	272	21.3	285	3.8	567	3.2	Aug. 1-31	90.8	80.0	−3.2	4.25	+2.38	8
Fullers	Aug. 17	482	25	0	0.0	0.0	0.0	0.0	23	0.0	0	0.0	2	0.0	Aug. 1-31	90.8	80.0	−3.2	4.25	+2.38	8
Goliad	Aug. 7-Sept. 3	2,660	1,428	661	46.3	19.3	19.0	8.5	407	46.7	256	30.0	334	3.0	Aug. 1-31	90.2	81.6	−0.9	1.52	+2.14	6
Hallettsville	Aug. 9-31	4,124	1,805	1,272	70.0	31.7	35.8	3.0	571	80.0	220	41.4	268	10.0	Aug. 1-31	95.0	84.6	+1.1	0.85	−1.54	3
Junction	Sept. 24	427	146	90	61.6	27.4	25.4	8.2	52	69.2	13	9.2	28	8.9	Sept. 1-30	90.9	79.0	+3.5	4.44	+2.80	7
Kerrville	Aug. 25-Sept. 3	546	330	34	10.3	3.0	4.0	3.3	239	4.2	51	0.0	12	0.0	Aug. 1-31	95.3	82.4	+1.2	3.47	+1.90	9
Lula	Sept. 26	324	105	12	11.4	2.0	10.0	0.0	50	4.0	23	0.0	10	0.0	......	......	......	......	......	......	......
Marshall	Aug. 22	452	93	37	40.0	17.2	16.1	7.5	40	32.5	17	11.8	15	6.7	Aug. 1-31	88.7	79.3	......	2.65	......	7
Mineola	Aug. 10-Oct. 2	1,075	502	258	51.4	31.5	17.9	2.0	215	36.4	138	48.0	49	28.4	......	......	......	......	......	......	......
Overton	Aug. 23	953	422	310	73.5	6.6	65.2	1.7	64	37.7	36	16.7	36	6.0	Aug. 1-31	......	80.3	......	3.11	......	8
Palestine	Aug. 10-Sept. 4	2,891	1,858	366	19.7	12.9	3.0	3.8	751	26.1	614	5.7	334	1.8	Aug. 1-31	89 4	80.5	+0.1	1.43	−1.25	11
Roosevelt	Sept. 24	350	224	58	25.9	7.1	13.8	5.0	109	13.0	42	4.8	29	0.0	Sept. 1-30	90.9	79.0	+3.5	4.10	......	7
San Antonio	Aug. 15	401	35	25	71.4	0.0	71.4	0.0	8	0.0	0	0.0	2	0.0	Aug. 1-31	91.9	82.0	−0.2	2.25	−1.59	9
Taylor	Aug. 16	797	306	50	16.3	11.8	1.3	3.3	170	21.0	82	2.4	31	0.0	Aug. 1-31	90.4	80.9	......	2.08	......	5
Terrell	Sept. 19	308	99	4	4.0	1.0	3.0	0.0	57	1.8	30	0.0	6	0.0	Sept. 1-30	89.2	77.9	......	3.96	......	6
Trinity	Aug. 9-30	8,637	2,966	1,499	50.5	10.4	37.7	2.4	1,011	25.7	292	11.3	295	5.1	Aug. 1-31	89.3	81.4	−1.4	1.79	−1.67	4
Victoria	June 16-Sept. 1	11,828	7,772	4,522	58.1	26.4	28.1	3.7	3,368	57.8	699	10.6	652	3.2	June 1-Sept. 30	91.2	82.1	−0.4	13.20	+0.45	28
Waco	July 25-Oct. 12	10,809	3,534	2,207	62.5	25.4	26.4	10.7	1,072	64.7	396	26.5	809	12.1	July 1-Sept. 30	92.	82.2	−0.7	15.99	+9.01	15
Total	......	86,956	38,991	20,285	52.0	20.7	27.0	4.3	12,568	52.6	5,663	18.0	6,773	6.3	......	......	......	......	......	......	......

[a] Includes each stage found alive or dead from effects of heat or drying, and also counts one for each weevil cell emptied by ants and for each instance of parasite occurrence.

[b] Weevil stages destroyed by ants could not be easily determined. Those destroyed by parasites could have been determined, but were not.

[c] In cases where weather records are not kept for the locality where examinations were made, the records from the nearest weather station having similar climatic conditions have been used.

Ants (*Solenopsis geminata*) accomplish a greater destruction of weevil stages than heat and parasites combined. Parasites are decidedly the least important of the three factors.

So many conditions influence the effect of sunshine especially that it is difficult to determine whether there exists anything like a constant relationship between the maximum temperatures at a locality and the mortality from heat or drying. In some cases a relationship is evident which can not be regarded as merely accidental. The localities in which a comparatively small series of examinations was made should not be considered in this connection.

The highest proportion of rainy days occurred at Calvert during July and August, being twenty-five in sixty-one days. The influence of each factor of natural control seems to have been greatly reduced by the excessive amount of rain (10.22 inches) distributed over so many days. The total mortality was but 15.1 per cent, distributed among the factors as follows: Heat 3.9 per cent, ants 9.3 per cent, parasites 2.1 per cent. The high maximum temperatures occurring were evidently prevented from exerting their usual influence by the almost continuously wet condition of the ground. This produced a high percentage of relative humidity which would naturally favor the development of the weevils.

Fortunately for this portion of our study an automatic self-registering combined thermograph and hydrograph had been located at Calvert early in the season of 1906, and the records from this machine furnish valuable data regarding humidity conditions which could not otherwise be obtained. These records may be used in connection with Weather Bureau reports for the locality of Calvert and some interesting facts will appear.

Around Calvert very light rains fell early in June, but from that time until June 25 there was no rainfall. The period from June 5 to June 25, 1906, shows an average relative humidity[a] amounting to about 69 per cent. From June 25 till after September 10 showers were of frequent occurrence and the records show during this period an average relative humidity of 75 per cent. Doubtless very significant facts might be learned if for other localities data similar to those obtained for Calvert were available for comparison.

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[a] Relative humidity is the term used to denote the proportion of atmospheric moisture which actually exists as compared with the amount of moisture which it would be possible for the air to contain at any given temperature. If the air contains all the moisture possible, it is said to be "saturated" and this is the condition during fogs and sometimes, though not always, during rains. It is the condition of the air at a given point when dew is deposited. The relative humidity under this saturated condition is 100 per cent. The condition opposite to this extreme is a perfectly dry air in which the relative humidity is 0. The amount of moisture, or water vapor, which it is possible for a given amount of air to contain is much greater if the air be warm than if it be cold. Thus, taking a certain quantity of air containing a definite quantity of water vapor, the percentage of relative humidity will increase as the temperature is lowered and decrease as the temperature is raised. A low percentage of relative humidity naturally promotes evaporation owing to absorption of the moisture by the drier air, while evaporation ceases, even from a water surface, when the air becomes saturated. During the summer in central Texas the relative humidity increases at a few feet above the ground during the nights until it reaches, as a rule, a maximum of between 90 and 95 per cent. During the day it decreases until in the warmest part of the afternoon it reaches a minimum of between 30 and 50 per cent.

INFLUENCE OF CLIMATIC CONDITIONS ESPECIALLY.

In further determining whether climatic conditions were the most important factors affecting the total mortality percentages, conclusions may be more readily drawn by arranging the data in three groups, ranging from the highest total mortality to the lowest. Group A may include the eleven localities having a total mortality above the average of 52 per cent, ranging from 84 to 52.5 per cent. Group B may include seven localities having a total mortality ranging from 51.4 to 39.4 per cent. The division between Group B and Group C is made because of the rather large difference in percentage of total mortality shown between 39.4 per cent, the lowest in Group B, and 28 per cent, the highest in Group C. Group C includes ten localities with the total mortality percentage ranging from 28 per cent to zero. Each group is summarized to facilitate a general comparison of the average results of the observations made and of the average climatic conditions prevailing. The data are presented in Table VII.

[illegible]LE VII.—*Comparison of mortality records, with localities arranged in percentage groups.*

GROUP A.—ELEVEN LOCALITIES HAVING ABOVE 52 PER CENT OF TOTAL MORTALITY.

Locality.	Date or period.	Total of four classes of forms examined.	Total weevil stages found.	Total stages killed by heat, ants, and parasites.	Total mortality from three causes.	Percentage of mortality from—			Mortality from heat or drying, by stages.						Climatic condition.						
									Larva.		Pupa.		Adult.		Period included.	Temperature F°.			Rainfall.		
						Heat or drying.	Ants.	Parasites.	Number of stages found.	Per cent of stages dead.	Number of stages found.	Per cent of stages dead.	Number of stages found.	Per cent of stages dead.		Mean maximum.	Mean average.	Departure from normal.	Total precipitation.	Departure from normal.	Number of rainy days.
	1906.				*P. ct.*										1906.				*Ins.*	*Ins.*	
Beeville, Tex.........	July 12–Oct. 1....	5,428	2,968	2,484	84.0	20.0	62.8	1.2	640	75.3	181	43.1	170	12.9	July 1–Aug. 31....	94.2	83.8	−1.35	5.49	+1.42	12
Overton, Tex.........	Aug. 23...........	953	422	310	73.5	6.5	64.1	1.6	64	37.7	36	16.7	36	6.0	Aug. 1–31..........	.....	80.3	......	3.11	......	8
San Antonio, Tex....	Aug. 15...........	401	35	25	71.4	0.0	71.4	0.0	8	0.0	0	0.0	2	0.0	....do............	91.9	82.0	−0.2	2.25	−1.59	9
Corpus Christi, Tex..	July 10...........	1,039	458	322	70.3	40.0	27.1	3.5	183	88.0	45	37.7	43	2.3	July 1–31.........	88.8	83.0	+1.3	0.41	−0.91	3
Hallettsville, Tex....	Aug. 9–31.........	4,124	1,805	1,272	70.0	31.7	35.8	3.0	571	80.0	220	41.4	268	10.0	Aug. 1–31.........	95.0	84.6	+1.1	0.85	−1.54	3
Cuero, Tex..........	Aug. 9–31.........	3,039	1,766	1,219	69.0	39.5	23.9	5.7	773	72.3	238	50.9	135	12.6	....do............	94.5	83.8	−1.0	2.43	+0.77	4
Waco, Tex..........	July 25–Oct. 12...	10,809	3,534	2,207	62.6	24.1	26.4	10.7	1,072	64.7	296	26.5	809	12.1	July 1–Sept. 30...	92.2	82.2	−0.7	15.99	+9.01	15
Junction, Tex........	Sept. 24..........	427	146	90	61.6	27.4	25.4	8.2	52	19.2	13	9.2	28	8.9	Sept. 1–30.........	90.9	79.0	+3.6	4.44	+2.80	7
Victoria, Tex........	June 16–Sept. 1...	11,828	7,772	4,522	58.1	26.4	28.1	3.7	3,368	57.8	699	10.6	652	3.2	June 1–Sept. 30...	91.2	82.1	−0.4	13.20	+0.45	28
Mansfield, La........	Aug. 24–Sept. 29..	4,324	1,562	872	56.1	13.6	39.2	3.2	234	50.1	152	36.2	453	8.6	Aug. 1–Sept. 30...	89.7	78.9	+1.5	7.37	......	16
Brownsville, Tex....	July 28–Sept. 5...	8,962	3,479	1,822	52.5	34.8	11.6	6.0	1,181	85.3	629	23.7	993	5.7	July 1–Aug. 31....	92.2	84.1	+0.9	8.83	+3.88	12
Totals and average percentages: Eleven localities...	....	52,334	23,947	15,145	63.2	27.0	31.5	4.8	8,146	67.4	2,609	26.6	3,589	8.0	Nineteen month-periods.	91.9	82.2	+0.17	3.39	+0.89	6.2

GROUP B.—SEVEN LOCALITIES HAVING BELOW 52 PER CENT OF TOTAL MORTALITY.

Mineola, Tex.........	Aug. 10–Oct. 2....	1,075	502	258	51.4	31.5	17.9	2.0	215	36.4	138	48.0	49	28.4	....	.....	.....	......	.....	......	...
Trinity, Tex.........	Aug. 9–30.........	8,637	2,966	1,499	50.5	10.4	37.7	2.4	1,011	25.7	292	11.3	295	5.1	Aug. 1–31.........	89.3	81.4	−1.4	1.79	−1.67	4
Goliad, Tex.........	Aug. 7–Sept. 3....	2,660	1,428	661	46.3	19.3	19.0	8.5	407	46.7	256	30.0	334	3.0	....do...........	90.2	81.6	−0.9	4.52	+2.14	6
Corsicana, Tex.......	Aug. 23–Sept. 18...	1,711	311	126	40.5	19.3	14.8	4.5	80	55.0	61	18.2	98	5.1	Sept. 1–30.........	90.9	79.7	+1.6	2.53	−0.71	7
Many, La............	Aug. 23...........	5,180	2,828	1,138	40.2	11.0	26.9	4.0	420	40.0	484	14.0	946	7.0	Aug. 1–31.........	92.9	80.6	......	0.58	−2.79	2
Marshall, Tex........	Aug. 22...........	452	93	37	40.0	17.2	16.1	7.5	40	32.5	17	11.8	15	6.7	....do............	88.7	79.3	......	2.65	......	7

Orangeville, La.	Aug. 23–Sept. 10	1,195	502	196	39.4	2.6	35.5	1.0	109	6.4	83	4.8	105	2.0	Aug. 1–Sept. 30	89.4	80.2	+2.0	6.01	−1.31	9
Totals and average percentages: Seven localities		19,910	8,630	3,915	45.4	13.0	26.0	3.8	2,282	33.0	1,331	19.3	1,852	6.0	Seven month-periods.	90.1	80.4	+0.56	2.6	−0.72	5

GROUP C.—TEN LOCALITIES HAVING BELOW 28 PER CENT OF TOTAL MORTALITY.

Dallas, Tex.	Aug. 29–Oct. 15	5,307	1,596	446	28.0	5.5	17.7	4.7	272	21.3	285	3.8	567	3.2	Aug. 1–31	90.8	80.0	−3.2	4.25	+2.38	8
Roosevelt, Tex.	Sept. 24	350	224	58	25.9	7.1	13.8	5.0	109	13.0	42	4.8	29	0.0	Sept. 1–30	90.9	79.0	+3.5	4.10	......	7
Palestine, Tex.	Aug. 10–Sept. 14	2,891	1,858	366	19.7	12.9	3.0	3.8	751	26.1	614	5.7	334	1.8	Aug. 1–31	89.4	80.5	+0.1	1.43	−1.25	11
Taylor, Tex.	Aug. 16	797	306	50	16.3	11.8	1.3	3.3	170	21.0	82	2.4	31	0.0	do	90.4	80.9	......	2.08	......	5
Calvert, Tex.	Aug. 22–Sept. 13	3,407	1,646	253	15.1	3.9	9.3	2.1	363	13.5	515	2.5	315	0.6	Aug. 1–Sept. 30	94.6	83.7	+1.5	10.22	+6.10	2.5
Lula, Tex.	Sept. 26	324	105	12	11.4	2.0	10.0	0.0	50	4.0	23	0.0	10	0.0	......	......	......	......	......	......	......
Kerrville, Tex.	Aug. 25–Sept. 3	546	330	34	10.3	3.0	4.0	3.3	239	4.2	51	0.0	12	0.0	Aug. 1–31	95.3	82.4	+1.2	3.47	+1.90	9
Terrell, Tex.	Sept. 19	308	99	4	4.0	1.0	3.0	0.0	57	1.8	30	0.0	6	0.0	Sept. 1–30	89.2	77.9	......	3.96	......	6
Johnsons Bayou, La.	Aug. 22–27	300	225	2	0.9	0.4	0.4	0.0	106	0.0	81	1.2	36	0.0	......	......	......	......	......	......	......
Fullers, Tex.	Aug. 17	482	25	0	0.0	0.0	0.0	0.0	23	0.0	0	0.0	2	0.0	Aug. 1–31	90.8	80.0	−3.2	4.25	+2.38	8
Totals and average percentages: Ten localities		14,712	6,414	1,225	19.1	7.1	8.7	3.3	2,140	17.1	1,723	3.7	1,342	2.0	Nine month-periods.	91.8	80.9	+0.01	3.75	+1.92	8.80
Summary of all sections below 52 per cent.		34,622	15,044	5,140	34.2	10.5	18.6	3.6	4,422	25.4	3,054	10.5	3,194	4.3	Sixteen month-periods.	91.9	80.7	+0.4	3.24	+0.6	7.1

TOTALS FOR EACH GROUP OF LOCALITIES.

Seven localities, Group B	19,910	8,630	3,915	45.4	13.0	26.0	3.8	2,282	33.0	1,331	19.3	1,852	6.0	Seven month-periods.	90.1	80.4	+0.56	2.6	−0.73	5.0
Ten localities, Group C	14,712	6,414	1,225	19.0	7.1	8.7	3.3	2,140	17.1	1,723	3.7	1,342	2.0	Nine month-periods.	91.8	80.9	+0.01	3.75	+1.92	8.8
Seventeen localities, Groups B and C	34,622	15,044	5,140	34.2	10.5	18.6	3.6	4,422	25.4	3,054	10.5	3,194	4.3	Sixteen month-periods.	91.9	80.7	+0.4	3.24	+0.60	7.1
Eleven localities, Group A	52,334	23,947	15,145	63.2	27.0	31.5	4.8	8,146	67.4	2,609	26.6	3,589	8.0	Nineteen month-periods.	91.9	82.2	+0.17	3.39	+0.89	6.2

TABLE VII.—*Comparison of mortality records, with localities arranged in percentage groups.*

GROUP A.—ELEVEN LOCALITIES HAVING ABOVE 52 PER CENT OF TOTAL MORTALITY.

Locality.	Date or period.	Total of four classes of forms examined.	Total weevil stages found.	Total stages killed by heat, ants, and parasites.	Total mortality from three causes.	Percentage of mortality from—			Mortality from heat or drying, by stages.						Climatic condition.						
									Larva.		Pupa.		Adult.			Temperature F°.			Rainfall.		
						Heat or drying.	Ants.	Parasites.	Number of stages found.	Per cent of stages dead.	Number of stages found.	Per cent of stages dead.	Number of stages found.	Per cent of stages dead.	Period included.	Mean maximum.	Mean average.	Departure from normal.	Total precipitation.	Departure from normal.	Number of rainy days.
	1906.				*P. ct.*										1906.				*Ins.*	*Ins.*	
Beeville, Tex	July 12-Oct. 1	5,428	2,968	2,484	84.0	20.0	62.8	1.2	640	75.3	181	43.1	170	12.9	July 1-Aug. 31	94.2	83.8	−1.35	5.49	+1.42	12
Overton, Tex	Aug. 23	953	422	310	73.5	6.5	64.1	1.6	64	37.7	36	16.7	36	6.0	Aug. 1-31	......	80.3	......	3.11	......	8
San Antonio, Tex	Aug. 15	401	35	25	71.4	0.0	71.4	0.0	8	0.0	0	0.0	2	0.0	.....do	91.9	82.0	−0.2	2.25	−1.59	9
Corpus Christi, Tex	July 10	1,039	458	322	70.3	40.0	27.1	3.5	183	88.0	45	37.7	43	2.3	July 1-31	88.8	83.0	+1.3	0.41	−0.91	3
Hallettsville, Tex	Aug. 9-31	4,124	1,805	1,272	70.0	31.7	35.8	3.0	571	80.0	220	41.4	268	10.0	Aug. 1-31	95.0	84.6	+1.1	0.85	−1.54	3
Cuero, Tex	Aug. 9-31	3,039	1,766	1,219	69.0	39.5	23.9	5.7	773	72.3	238	50.9	135	12.6	.....do	94.5	83.8	−1.0	2.43	+0.77	4
Waco, Tex	July 25-Oct. 12	10,809	3,534	2,207	62.6	24.1	26.4	10.7	1,072	64.7	296	26.5	809	12.1	July 1-Sept. 30	92.2	82.2	−0.7	15.99	+9.01	15
Junction, Tex	Sept. 24	427	146	90	61.6	27.4	25.4	8.2	52	19.2	13	9.2	28	8.9	Sept. 1-30	90.9	79.0	+3.6	4.44	+2.80	7
Victoria, Tex	June 16-Sept. 1	11,828	7,772	4,522	58.1	26.4	28.1	3.7	3,368	57.8	699	10.6	652	3.2	June 1-Sept. 30	91.2	82.1	−0.4	13.20	+0.45	28
Mansfield, La	Aug. 24-Sept. 29	4,324	1,562	872	56.1	13.6	39.2	3.2	234	50.1	152	36.2	453	8.6	Aug. 1-Sept. 30	89.7	78.9	+1.5	7.37	......	16
Brownsville, Tex	July 28-Sept. 5	8,962	3,479	1,822	52.5	34.8	11.6	6.0	1,181	85.3	629	23.7	993	5.7	July 1-Aug. 31	92.2	84.1	+0.9	8.83	+3.88	12
Totals and average percentages: Eleven localities	....	52,334	23,947	15,145	63.2	27.0	31.5	4.8	8,146	67.4	2,609	26.6	3,589	8.0	Nineteen month-periods.	91.9	82.2	+0.17	3.39	+0.89	6.2

GROUP B.—SEVEN LOCALITIES HAVING BELOW 52 PER CENT OF TOTAL MORTALITY.

Locality.	Date or period.	Total of four classes of forms examined.	Total weevil stages found.	Total stages killed by heat, ants, and parasites.	Total mortality from three causes.	Heat or drying.	Ants.	Parasites.	Larva: Number of stages found.	Larva: Per cent of stages dead.	Pupa: Number of stages found.	Pupa: Per cent of stages dead.	Adult: Number of stages found.	Adult: Per cent of stages dead.	Period included.	Mean maximum.	Mean average.	Departure from normal.	Total precipitation.	Departure from normal.	Number of rainy days.
Mineola, Tex	Aug. 10-Oct. 2	1,075	502	258	51.4	31.5	17.9	2.0	215	36.4	138	48.0	49	28.4	....	......	......	......	......	......	......
Trinity, Tex	Aug. 9-30	8,637	2,966	1,499	50.5	10.4	37.7	2.4	1,011	25.7	292	11.3	295	5.1	Aug. 1-31	89.3	81.4	−1.4	1.79	−1.67	4
Goliad, Tex	Aug. 7-Sept. 3	2,660	1,428	661	46.3	19.3	19.0	8.5	407	46.7	256	30.0	334	3.0	.....do	90.2	81.6	−0.9	4.52	+2.14	6
Corsicana, Tex	Aug. 23-Sept. 18	1,711	311	126	40.5	19.3	14.8	4.5	80	55.0	61	18.2	98	5.1	Sept. 1-30	90.9	79.7	+1.6	2.53	−0.71	7
Many, La	Aug. 23	5,180	2,828	1,138	40.2	11.0	26.9	4.0	420	40.0	484	14.0	946	7.0	Aug. 1-31	92.9	80.6	......	0.58	−2.79	2
Marshall, Tex	Aug. 22	452	93	37	40.0	17.2	16.1	7.5	40	32.5	17	11.8	15	6.7	.....do	88.7	79.3	......	2.65	......	7

Orangeville, La......	Aug. 23-Sept. 10...	1,195	502	196	39.4	2.6	35.5	1.0	109	6.4	83	4.8	105	2.0	Aug. 1-Sept. 30....	89.4	80.2	+2.0	6.01	−1.31	9
Totals and average percentages: Seven localities.....	....	19,910	8,630	3,915	45.4	13.0	26.0	3.8	2,282	33.0	1,331	19.3	1,852	6.0	Seven month-periods.	90.1	80.4	+0.56	2.6	−0.72	5

GROUP C.—TEN LOCALITIES HAVING BELOW 28 PER CENT OF TOTAL MORTALITY.

Dallas, Tex..........	Aug. 29-Oct. 15...	5,307	1,596	446	28.0	5.5	17.7	4.7	272	21.3	285	3.8	567	3.2	Aug. 1-31.........	90.8	80.0	−3.2	4.25	+2.38	8
Roosevelt, Tex.......	Sept. 24...........	350	224	58	25.9	7.1	13.8	5.0	109	13.0	42	4.8	29	0.0	Sept. 1-30.........	90.9	79.0	+3.5	4.10	......	7
Palestine, Tex.......	Aug. 10-Sept. 14...	2,891	1,858	366	19.7	12.9	3.0	3.8	751	26.1	614	5.7	334	1.8	Aug. 1-31.........	89.4	80.5	+0.1	1.43	−1.25	11
Taylor, Tex..........	Aug. 16...........	797	306	50	16.3	11.8	1.3	3.3	170	21.0	82	2.4	31	0.0	.....do............	90.4	80.9	......	2.08	......	5
Calvert, Tex.........	Aug. 22-Sept. 13...	3,407	1,646	253	15.1	3.9	9.3	2.1	363	13.5	515	2.5	315	0.6	Aug. 1-Sept. 30....	94.6	83.7	+1.5	10.22	+6.10	2.5
Lula, Tex...........	Sept. 26..........	324	105	12	11.4	2.0	10.0	0.0	50	4.0	23	0.0	10	0.0	....	......	......	......	......	......	....
Kerrville, Tex.......	Aug. 25-Sept. 3....	546	330	34	10.3	3.0	4.0	3.3	239	4.2	51	0.0	12	0.0	Aug. 1-31.........	95.3	82.4	+1.2	3.47	+1.90	9
Terrell, Tex..........	Sept. 19..........	308	99	4	4.0	1.0	3.0	0.0	57	1.8	30	0.0	6	0.0	Sept. 1-30.........	89.2	77.9	......	3.96	......	6
Johnsons Bayou, La.	Aug. 22-27........	300	225	2	0.9	0.4	0.4	0.0	106	0.0	81	1.2	36	0.0	....	......	......	......	......	......	....
Fullers, Tex	Aug. 17...........	482	25	0	0.0	0.0	0.0	0.0	23	0.0	0	0.0	2	0.0	Aug. 1-31.........	90.8	80.0	−3.2	4.25	+2.38	8
Totals and average percentages: Ten localities.......	....	14,712	6,414	1,225	19.1	7.1	8.7	3.3	2,140	17.1	1,723	3.7	1,342	2.0	Nine month-periods.	91.8	80.9	+0.01	3.75	+1.92	8.80
Summary of all sections below 52 per cent.	....	34,622	15,044	5,140	34.2	10.5	18.6	3.6	4,422	25.4	3,054	10.5	3,194	4.3	Sixteen month-periods.	91.9	80.7	+0.4	3.24	+0.6	7.1

TOTALS FOR EACH GROUP OF LOCALITIES.

Seven localities, Group B	19,910	8,630	3,915	45.4	13.0	26.0	3.8	2,282	33.0	1,331	19.3	1,852	6.0	Seven month-periods.	90.1	80.4	+0.56	2.6	−0.73	5.0
Ten localities, Group C..................	14,712	6,414	1,225	19.0	7.1	8.7	3.3	2,140	17.1	1,723	3.7	1,342	2.0	Nine month-periods.	91.8	80.9	+0.01	3.75	+1.92	8.8
Seventeen localities, Groups B and C.....	34,622	15,044	5,140	34.2	10.5	18.6	3.6	4,422	25.4	3,054	10.5	3,194	4.3	Sixteen month-periods.	91.9	80.7	+0.4	3.24	+0.60	7.1
Eleven localities, Group A...............	52,334	23,947	15,145	63.2	27.0	31.5	4.8	8,146	67.4	2,609	26.6	3,589	8.0	Nineteen month-periods.	91.9	82.2	+0.17	3.39	+0.89	6.2

From the eleven localities in Group A 52,334 forms were examined. This number constitutes 60.2 per cent of the total of the three groups. In these forms were found 23,947 weevil stages. This number constitutes 61.4 per cent of the total number of weevil stages found in the three groups. The proportion of weevil stages to forms examined in each of the groups varies but slightly. When we come to the total number of weevil stages killed by the three factors, we find in Group A 15,145 dead, which number is 74.7 per cent of the total mortality occurring in the three groups. This shows that in Group A there was actually an increase of nearly 15 per cent in the total mortality above the average proportion which might have been expected in this group. The average mortality occurring in Group A is 63.2 per cent. The percentage of mortality in Group A from each of the three factors is somewhat greater than the average shown in Table VI. For heat and drying this increase amounts to 6.3 per cent, for ants to 4.5 per cent, for parasites to 0.5 per cent. The greatest increase is therefore attributable to heat or drying and it might naturally be expected that the climatic records would show a considerably higher maximum temperature to account for this increased mortality. A comparison of the mean maximum temperature records for Group A with those for Groups B and C shows, however, an average difference of less than 2 degrees. Between A and C there is an average difference of but 0.1 degree. In group A 27 per cent of the weevil stages found were destroyed by heat or drying, while in Group C, having almost identically the same mean maximum temperature, the mortality from this cause is but 7.1 per cent—a decrease in Group C of 19.9 per cent.

The percentage of mortality from ants shows an even greater difference between Groups A and C than has just been shown for heat, amounting in this case to a decrease of 22.8 per cent. Certainly this difference can not be attributed to the variations in temperature shown for these groups.

While unquestionably an unusual deficiency of rainfall is very important in checking the development of weevils, the difference shown in this table for the average monthly rainfall in each of the three sections can not account for the difference found in the total mortality from any of the three factors. Thus in Group A, having a monthly average of 3.39 inches, which is 0.89 of an inch above the average normal rainfall for the localities given, and an average of 6.2 rainy days per month, the mortality from heat or drying averages 27 per cent. In Group B, for seven localities the average total rainfall is 2.6 inches per month. For these localities this is a deficiency amounting to 0.72 inches per month. We have here five rainy days per month and the mortality from heat or drying is but 13 per cent, or less than one-half the mortality found in Group A. Similarly, in Group C, with a mean maximum temperature approximately the same as that in Group A and a total rainfall for each month averaging 3.75 inches, which is 1.92 above the normal, there is a total mortality from all three causes averaging but 19.1 per cent, while that from heat alone averages but 7.1 per cent. A comparison of the mortality from ant work between Groups A and C shows in C a decrease which is very nearly proportional to that found for heat, while the reduction in parasite work is comparatively slight.

These facts seem to point to the conclusion that other factors than climatic conditions must explain the variations in mortality which are shown in this table. Undoubtedly *extreme* variations in temperature and rainfall are exceedingly important, but it is obvious that the *average* variation in these factors does not produce a corresponding variation in the mortality figures, such as might be expected. Evidently there are other factors modifying or neutralizing the effect of climatic variations, which if acting alone might produce more consistent results.

INFLUENCE OF CULTURAL CONDITIONS.

High temperature can affect the weevil stages only after the forms have fallen or been so cut off from vital connection with the plant that the sap flow is stopped and a drying of the form results. The effect upon the weevil stage will then depend upon the conditions of exposure to the heat. If the square or boll remains hanging or dries upon the plant, the temperature in it will not rise as high as if those forms were exposed directly to sunshine upon the surface of the ground. If the square or boll falls to the ground, its position in regard to the shade of the plant will determine largely the degree of exposure to the heat of the sun and, consequently, the probability as to the survival or destruction of an inclosed weevil stage. The direction in which the rows run, and more especially the open distance between plants, will affect the exposure of the fallen forms to the direct action of the sun. The dryness of the surface soil is another factor which will largely affect the drying of the forms and the mortality resulting from heat. The work of the living larvæ naturally produces a larger degree of moisture in the infested forms than will be found in those which contain no weevil stage. If the conditions are such as to insure a very rapid and complete drying of the form within a few days after it falls to the ground, there is a strong probability that the weevil stages affected will be destroyed by heat or drying. If climatic or environmental conditions favor the weevil's development until the pupal stage is reached, the condition of the form is then much more favorable for the entrance and attack of the ants. The ants seem to be able to recognize the presence of a living weevil stage within a form and rarely, if ever, enter forms in which the stages have previously been destroyed by heat. If ants destroyed both parasite and weevil stages no evidence of the parasitism might remain. It is possible that the indiscriminate work of ants may explain, in part at least, the fact that fallen forms have invariably yielded a smaller percentage of parasites than have hanging forms. Referring to Table III, this difference in the percentage of parasite attack is shown as follows: In hanging bolls, 6 per cent; in hanging squares, 12.8 per cent; in fallen bolls, 1 per cent; in fallen squares, 3.2 per cent. As the ants are already distributed in the cotton fields throughout the weevil-infested area, it is evident that their relative abundance in different localities may explain to a considerable extent the variations which have been found in the percentage of mortality resulting from ant attack.

It has been found that all of the parasites which attack the weevil are native species having some other host which lives normally in some part of the vegetation surrounding the cotton fields. In no case can the weevil be considered as the primary or preferred host of any of these species. It has been found that in many instances the occurrence of other weevils, living under such diverse conditions as in the buds, flowers, fruit, seeds, stems, roots, or in galls formed by the attack of some other insect, a large variety of weeds, or other common plants and of trees, directly influences the abundance of parasite species and explains variations which have been found in the extent of parasite attack upon the boll weevil. It is plain, then, that the abundant occurrence of some plant supporting a large number of other weevils which do not at all affect cotton may produce indirectly an abundance of some parasite species which is capable of attacking the weevil. It is to be hoped that some of these parasites may ultimately develop a preference for the boll weevil as their host. This would seem to be a possibility, because the boll weevil presents a continuous series of stages for parasite attack throughout the season, whereas in many cases it is known that parasites are forced by the short breeding season of their original host to change from one host to another in order to continue their own reproduction throughout the season. The tendency of parasites to adapt themselves to this change in possible host conditions demands continued careful investigation.

The note records concerning cultural conditions in the various fields investigated are not as complete as is desirable for this study, but a general summary of conditions as noted will be given to determine the possibility that cultural conditions may explain some of the variations which have been found in mortality. In Table VIII, Group A, the cultural notes are given for most localities recorded in Table VII, Group A. The same arrangement in regard to total mortality is retained.

TABLE VIII.—*Comparison of cultural and other conditions, with localities arranged as in Table VII.*

GROUP A.

Locality.	Total mortality.	Date of cultural notes.	Nature of soil.	Direction of rows.	Spacing of plants.	Condition of cultivation.	Remarks.
	Per cent.	1906.					
Beeville, Tex	84.0	July 12	Black; sandy	N.-S.	Where stand, one-half shade.		Blooming freely many dried fallen squares. Inf. 84 per cent 1,000 square lot.
Beeville, Tex	84.0	Aug. 8–Sept. 3	Black; sandy	E.-W	Rows 4 feet		Well budded; squares down to middle of plants.
Overton, Tex	73.5	Aug. 23	Sandy upland		3 by 1½	Fair	Cotton grown in clearings in pine forest. Plants small.
San Antonio, Tex	71.4						
Corpus Christi, Tex	70.3	July 10	Black; sandy	NNW.-SSE	Even stand; ground two-fifths shade.	Well tilled	Cotton opening. Ground very dry and cracked.
Hallettsville, Tex	70.0	Aug. 31	Post-oak	2 fields; N.-S.	3 by 1½		Cotton opening. Dead in many places; green in patches.
Cuero, Tex	69.0	Aug. 31	Black	NW.-SE	3½ by 1½		Picked over once. Squares scarce. Many bolls.
Waco, Tex	69.0	Aug. 28	Loose gray		3½ by 1½		Davis field. Stalk medium, foliage not dense. Solenopsis numerous. Weaver field: Part of examination in rank, part in small cotton. Ants not abundant.
	69.0	Aug. 29	Mixed				
Junction, Tex	61.6	Sept. 24	Medium brown; sandy.	N.-S.	3 by 1½	Rank cotton and weeds.	Wet season. Irrigated field; alternate corn and cotton.
Victoria, Tex	58.1	June 22	Black bottom	NE.-SW	Stand poor, 3½ by 1½	Not well cultivated	½ acre. Very dry May and June. Solenopsis fairly abundant.
	58.1	July 1	Black bottom	E.-W	½ shaded, 4 by 1½	Well cultivated	Plant breeding plat. Plants large, Guadaloup bottom.
	58.1	July 18	Black bottom	E.-W	4 by 1½	Fairly cultivated	
Mansfield, La	56.1	Aug. 24	Sandy; rolling	E.-W	4 by 1½		A fair field. Plants defoliated by rust. King, early planted. Solenopsis very numerous.
Brownsville, Tex	52.5	July 28	Black loam				Dorsett field. Planted Feb. 1. Fallen squares.
	52.5	Sept. 5	Black mesquite		Dying in places		Many fallen squares. Picked over once. Some leaf-worm work.

TABLE VIII.—*Comparison of cultural and other conditions, with localities arranged as in Table VII*—Continued.

GROUP B.

Locality.	Total mortality.	Date of cultural notes.	Nature of soil.	Direction of rows.	Spacing of plants.	Condition of cultivation.	Remarks.
	Per cent.	1906.					
Mineola, Tex.	51.4	Aug. 10	Deep sand	E.-W.	3½ by 1½	Good	Plants large. Fertilized. Very dry and hot.
Trinity, Tex.	50.5	Aug. 9	Sandy	E.-W.	4 by 1		Large part of leaves fallen from rust. Many Solenopsis seen. Much rain for past five weeks.
Trinity, Tex.	50.5	Aug. 30	Black, almost wax	N.-S.	4 by 1½		Plants shade only portion of ground. Fair number Solenopsis.
Goliad, Tex.	46.3	Aug. 7	Black loam	N.-S.	4½ by 1½		
Corsicana, Tex.	40.5	Aug. 23	Sandy	N.-S.	4 by 1½		
Many, La.	40.2	Aug. 23	Sandy with humus				Fair number Solenopsis.
Marshall, Tex.	40.0	Aug. 22	Sandy upland		3 by 1½	Good	Cotton grown in clearings in pine forest.
Orangeville, La.	39.4	Sept. 30	Deep sandy	N. E.-S. W.	3 by 1½	Fair	Few squares present. Nearly defoliated by leaf worm. Plants fair size.

GROUP C.

Locality.	Total mortality.	Date of cultural notes.	Nature of soil.	Direction of rows.	Spacing of plants.	Condition of cultivation.	Remarks.
Dallas, Tex.	28.0	Oct. 1	Black prairie	N.-S.	4 by 1½	Fairly good	Solenopsis quite numerous. Considerable root rot, causing dead areas.
Roosevelt, Tex.	25.9	Sept. 24	Dark sandy loam	E.-W.	3 by 1½		Plants average 4½ feet high.
Palestine, Tex.	19.7	Aug. 10	Sandy hillside	N.-S.	3½ by 1¼		Solenopsis apparently not abundant. Heavy foliage; ground partially shaded.
Taylor, Tex.	16.3						No record.
Calvert, Tex.	15.1	Sept. 1	Black bottom	NE.-SW.	4 by 1½	Good	Cotton rank; ground shaded.
Lula, Tex.	11.4	Sept. 26	Dark sandy loam		3 by 1⅓		Plants about 3½ feet high.
Kerrville, Tex.	10.3	Aug. 25	Dark sandy loam	N.-S.	3 by 1¼		Plants about 3 feet high.
Terrell, Tex.	4.0						No record.
Johnsons Bayou, La.	0.9						Do.
Fullers, Tex.	0.0						Do.

From a careful study of Table VIII it is quite evident that no single cultural factor will be found to explain the varying mortality. The character of the soil in each group varies from sandy postoak to black river bottom. The direction of the rows fails to show any consistent relationship to the proportion of weevil stages destroyed. The condition of cultivation was recorded for but few fields, and may practically be disregarded because of the lack of data. In the column for spacing of plants among the remarks are some points which were undoubtedly influential in producing the mortality results shown. Table VIII should be studied in connection with Table VII. At Beeville it was noted that the stand was poor and that only one-half of the ground was shaded where the stand was good. A large proportion of the squares were infested as early as July 12, and fallen, drying squares were abundant on the ground. Referring to Table VII in connection with Table VIII, it will be seen that under these conditions, with only fallen squares and bolls examined, the mortality from heat was quite large, but that caused by ants was relatively more than three times as great. Had the ants not been so active, it is very likely that the percentage of mortality from heat would have been very much greater. As it was, so many weevil stages were destroyed by the ants soon after the forms had fallen that the mortality from heat was kept comparatively low.

At Beeville about the middle of July the cultural notes indicate that the stand was uneven and that at best only about one-half of the ground was shaded. During July and August the climatic records show that the temperature averaged 1.5 degrees below normal, while the rainfall amounted to 1.42 inches above normal. Doubtless the excess of rainfall and the deficiency of heat are correlated. Under these conditions, however, there occurs the highest total mortality found in any locality, i. e., 84 per cent. Of this total mortality heat and drying was responsible for 20 per cent, while ants destroyed 62.8 per cent. In this case, therefore, it is evident that the ants were far the most important factor in producing the highest recorded percentage in mortality, and it would appear that their work was favored by the conditions of open spacing, medium heat, and much moisture.

At Overton the ants caused an even greater proportion of the total mortality than is shown above for Beeville. At San Antonio the examinations were not extensive, but the ants were responsible for the entire mortality found. In these three cases of highest total mortality the climatic factors would seem to have been much less important than was the abundance of the ants, which might have been influenced by local conditions.

At Corpus Christi all of the examinations were made on July 10. The notes show that at that time the ground was about two-fifths shaded, while it was very dry and had cracked deeply. The temperature records at Corpus Christi (Table VII) show far less range in temperature than is found at most of the other localities, which are all situated farther from the coast. The mean maximum temperature, therefore, appears to be relatively low, although the mean average temperature is 1.3 degrees above the normal for that locality. The weather records for May show that the temperature averages 1.3 degrees above normal, while during that month the rainfall was 1.78 inches below normal. June records show that the temperature averaged 1.7 degrees above normal, while rainfall was 1.63 inches below normal. July was also warm and dry, so that in this case the 40 per cent of mortality ascribed to heat or drying is very evidently the result of the extreme drought which had prevailed during the preceding eight or ten weeks. The high total mortality at Corpus Christi appears, therefore, to be largely a direct result of the extreme drought in a very open field, together with the active assistance of the ants.

At Hallettsville during August occurred the highest mean maximum temperatures found in any locality except Kerrville, although the mean average temperature was only 1.1 degrees above normal. The rainfall recorded was 1.54 inches below normal for the month. The full effect of this drought was probably not realized because of the fact that during the month there were traces of rain upon eleven days, when the precipitation was not sufficient to be measured. The cotton was dying in places and green in patches, so that forms must have been largely exposed, and the high temperature and drought should have produced an even higher mortality than the 31.7 per cent found for this factor. The effect is probably also modified by the fact that during July nearly the normal amount of rain had fallen, so that the ground during August was not nearly as dry as it was at Corpus Christi during July. At Hallettsville, also, ants were responsible for more than the average percentage of mortality. An explanation of the reasons for the great difference shown in the effect of heat, especially between Hallettsville and Kerrville, may be given at this point. A direct comparison of the Weather Bureau records will show at a glance how the influence of one important factor may be essentially affected by other related factors, and in this case it will afford an ample explanation of the mortality from heat, amounting to 31.7 per cent at Hallettsville, with a mean maximum temperature of 95 degrees, and only 3 per cent at Kerrville, with a similar temperature of 95.3 degrees.

TABLE IX.—*Explanation of variation in temperature effects at Hallettsville and Kerrville, Tex.*

Locality.	Temperature conditions.						Rainfall and cloud conditions.					
	Absolute maximum.		Average.		Mean average for month.	Departure from normal.	Rainfall.			Cloudiness.		
	Degrees Fahrenheit.	Number of days occurring.	Maximum.	Minimum.			Total.	Departure from normal.	Number of rainy days.	Number of days cloudy.	Number of days partly cloudy.	Number of days clear.
			°F.	°F.	°F.	°F.	In.	Inches.				
Hallettsville	99	5	95.0	74.1	84.6	+1.1	0.85	−1.54	3	6	11	14
Kerrville	98	2	95.3	69.5	82.4	+1.2	3.47	+1.90	9	14	13	4

Such differences as those shown in rainfall and cloud conditions are entirely sufficient to explain the difference in the effectiveness of similar maximum temperatures.

At Cuero the month of June was extremely hot and dry, showing a temperature averaging 4.6 degrees above normal and rainfall 2.04 inches below normal. These conditions are probably responsible for the major portion of the crop that was set in that locality. During July there was an excess of rainfall amounting to 2.63 inches, while during August the excess amounted to 0.77 inch. While the mean average temperature for August was 1 degree below normal, the mean maximum temperature ranged very high. In this case it appears that the mortality from heat or drying, amounting to 29.5 per cent, was due not so much to drought as to the fact that the maximum temperature experienced during the month reached 95 degrees or higher upon nineteen days. In this case, apparently, heat may have been the important factor rather than drying.

At Waco, Junction, and Victoria, Tex., the mortality is very evenly divided between heat and ants, the excess at Waco being due to a much larger percentage of parasitism. At Brownsville a large proportion of the mortality appears to have been due to heat, and this would seem to be a natural condition for that locality.

The study of the data shown in Tables VII and VIII for the localities in Group B indicates similar conclusions for those shown for Group A. At Mineola, in a total mortality of 51.4, 31.5 per cent was due to heat or drying, and the remarks state that it was "very dry and hot" at the time the collection was made.

At Trinity, with 50.5 per cent mortality, but 10.4 per cent was due to heat, while the destruction of stages by ants amounted to 37.7 per cent. The remarks show that although a large portion of the leaves had fallen from the plants because of a fungous disease, the excessive amount of rainfall would naturally prevent a large mortality from heat or drying, while the presence of "many Solenopsis" directly explains the large proportion of the total mortality which was due to their work. During July the rainfall amounted to 8.36 inches, amply justifying the remark, "Much rain for past five weeks," and fully explaining the low mortality from heat or drying.

The remaining localities given in Group B and those which have been included in Group C show a continual decrease in total mortality. The decrease is more evident from the effects of heat or drying and from ant attack than it is from the attack of parasites. Thus in Group B the average weighted percentage of mortality from the parasite attack is 3.8, while in Group C it is 3.3 per cent. From ant work in Group B there is a weighted average mortality of 26 per cent, while in Group C it averages 8.7. Mortality from heat or drying in Group B is 13 per cent, while in Group C it is but 7.3 per cent. It is evident that the extent of ant and parasite attack will be directly influenced more by the abundance of the species concerned than by the climatic conditions under which they may work. It is impossible to determine whether ants or parasites are particularly abundant in any locality except by determining the proportion of weevil stages which they have destroyed, but the primary actual cause of their abundance may depend upon very different conditions.

It is possible that the ants might be quite abundant and still attack the weevil stages but little if some other food supply were more easily available. It is manifestly more difficult to determine why mortality is low in a field than it is to determine what are the effective factors when it is high. From a comparison of Groups A and C in Table VIII it would appear that in Group A the predominant type of soil is sandy, while in Group C the soil is heavier and probably would tend to give a ranker growth of weed. This conclusion seems to be borne out by the remarks given for Group C, which indicate a heavy growth and a large degree of shade. This condition would decrease the efficiency of sunshine, and it is quite likely also that the soil conditions in these fields were not as favorable to the ants as in the more sandy locations.

It has been generally considered that the weevil has done greater damage in river bottoms than in upland fields. This has been held to be due to the greater moisture of the bottom lands and the ranker growth of the plants grown thereon. From the considerations which have been mentioned it would appear that this idea is well founded, but that the difference is due in a possibly equal degree to the absence of ants in the river bottoms. If this be true, then the importance of strictly cultural methods in controlling the weevils in the bottom lands may be even greater than it is on uplands, since as a general rule the factors of natural control may be less effective in such locations. It is evident, however, that there is no definite line of division between the localities in which natural control will be most effective and those in which it will be least so. Only by continuing observations for several years will it be possible to determine at all definitely the class of locations which will benefit most largely by the average effectiveness of these factors of natural control.

INFLUENCE OF PERIOD OF INFESTATION UPON NATURAL CONTROL.

A rearrangement of the data given in Tables III and V may be used to give a comparison of the results according to the classes of forms examined for Louisiana and for Texas. The separation of the data for the two States is made to enable a comparison as to mortality in a recently infested area, as in Louisiana, with an area which has been infested for a considerable time, as is the case with nearly all the localities examined in Texas.

TABLE X.—*Summary of results showing mortality in Louisiana and Texas resulting from heat or drying, ants, and parasites.*

State and class of fruit.	Total number of forms examined.	Total number of weevil stages found.	Total number of weevil stages dead.	Total mortality by three causes.	Weevil stages killed.					
					Heat or drying.		Ants.		Parasites.	
					Number.	Per cent of total stages.	Number.	Per cent of total stages.	Number.	Per cent of total stages.
Louisiana:				*Per ct.*						
Hanging bolls	2,955	1,163	458	39.4	137	11.8	252	21.7	69	6.0
Hanging squares	1,268	847	519	61.3	175	20.7	274	32.3	70	8.3
Fallen bolls	2,606	599	200	33.4	54	9.0	141	23.5	5	0.8
Fallen squares	4,170	2,508	1,031	41.1	160	6.4	859	35.7	12	0.7
Total, Louisiana	10,999	5,117	2,208	43.2	526	10.3	1,526	29.8	156	3.0
Texas:										
Hanging bolls	14,404	4,270	1,192	27.0	289	6.8	650	15.2	253	6.0
Hanging squares	5,736	3,383	1,708	50.5	629	18.6	609	18.2	470	13.9
Fallen bolls	20,079	4,019	1,323	32.9	473	11.8	810	20.2	40	1.0
Fallen squares	35,738	22,202	13,854	62.7	6,141	27.8	6,947	31.3	770	3.5
Total, Texas	75,957	33,874	18,077	53.5	7,532	22.3	9,016	26.7	1,533	4.6
Total, Louisiana and Texas	86,956	38,991	20,285	52.0	8,058	20.7	10,542	27.1	1,689	4.3

Naturally the examinations in Texas cover a much larger number of forms than do those in Louisiana, amounting to 87.4 per cent of the total for the two States. The Louisiana forms show a slightly greater proportion of weevil stages to forms examined than do those from Texas, in the former case the proportion being one weevil stage to each 2.15 forms, in the latter State one weevil stage per 2.25 forms. This difference is, of course, but slight.

In comparing the mortality results for the two States it appears that in Texas the total mortality averaged fully 10 per cent higher than it did in Louisiana. The smaller mortality found in Louisiana, being inevitably connected with a higher proportion of weevil development, doubtless explains sufficiently the slightly higher proportion of weevil stages to forms examined which was found in that State. A comparison of the mortality from each of the three factors shows that in Texas the mortality from heat or drying and from parasites exceeds that from these causes in Louisiana, while in the latter State the proportion of mortality due to the work of ants is slightly greater than that found in Texas. Nearly all of the excess in total mortality found in Texas is shown to be due to heat or drying. A sufficient explanation for this difference in the effect of heat in the two States is not brought out by the notes. By reference to Table VII it may be seen that only one locality in Louisiana (Mansfield) is to be found in Group A, which contains those localities having a total mortality greater than 52 per cent. In that case it is quite evident that ants were responsible for about three-fourths of the total mortality found. It is also evident that the mortality from heat in that locality was greater than at any other locality examined in Louisiana. This was doubtless due to the early defoliation of the plants by rust, but even in this case it was hardly equal to one-half of the average mortality from heat found in Group A. In Table VIII it is shown that all of the fields examined in Louisiana had a sandy soil. This soil condition may have been related in some way to the larger mortality from ant work and to the smaller mortality from heat or drying, but further observations are needed to definitely determine the correctness of this supposition. It is noticeable that parasites are somewhat more active in Texas than in Louisiana, and the difference shown probably indicates fairly correctly the degree of adaptation to weevil conditions which the Texas parasites have undergone. This seems especially true in view of the fact that a general average of observations upon parasite attack made in Texas four years ago also showed 3 per cent, as do the Louisiana localities in 1906.

In comparing the figures given for each class of forms in the two States some peculiar conditions are noticeable. Among hanging forms in Louisiana the total mortality averaged 48.6 per cent, while for the same class of forms in Texas the total mortality averaged but 37.9 per cent. On the other hand, for fallen forms in Louisiana the average was 39.6 per cent, while in Texas it was 57.9 per cent. The reason why the percentage of mortality is higher in hanging forms than it is in fallen forms in Louisiana while it is higher in fallen than in hanging forms in Texas is not apparent. A tabular statement of these differences presents them most clearly:

State and class of forms.		Mortality caused by—			Total mortality.
		Heat.	Ants.	Parasites.	
Louisiana	Hanging	15.5	26.2	6.9	48.6
	Fallen	6.9	32.2	0.5	39.6
Texas	Hanging	12.0	16.5	9.4	37.9
	Fallen	25.3	29.7	3.1	57.9

The conclusion that is strikingly apparent is that, for some reason, the mortality among the forms on the ground is much greater in Texas than it is in Louisiana from the factor of heat or drying. As is shown in Table VII, the temperature differences are not sufficient to account for the disparity if the conditions of exposure to the sunshine were at all similar. The difference of 3.5 per cent among the hanging forms is not great and it seems reasonable to assume that a generally more dense shade may have protected the fallen forms in Louisiana. This would possibly favor ant work but be unfavorable for destruction by heat and by parasites in fallen forms.

From Table X, as a basis of comparison of areas which have been infested for different periods of time, it appears that in the territory infested but about two years the parasite attack amounts to only about two-thirds as much as it does where the weevils have been present for an average of five years. In neither case are they sufficiently abundant to be considered as a factor of great importance at present, but recent experiments indicate that it may be possible to greatly increase their utility in the future. The Solenopsis ants do not seem to require a long period of time to become accustomed to the weevil's presence, but attack the stages readily and probably in proportion to the abundance of the ants. It would seem that the effectiveness of heat may have been increased by the methods of cultivation of cotton which have been adopted by the planters in the older infested region in Texas.

EFFICIENCY OF NATURAL CONTROL IN VARIOUS SECTIONS.

In the sectional reports of the Weather Bureau for Texas the localities from which observations are reported are divided into seven sections, according to their geographic location and their similarity in regard to climatic conditions. In making a more detailed locality study of the natural control of the boll weevil, it seems advisable to group the localities which have been examined upon the same general basis as has been done in grouping them for weather observations. The first two groups, western Louisiana and eastern Texas, have very similar conditions of climate, soil, flora, and fauna. In the group designated as southern Texas are found those localities which are included in the Weather Bureau reports as in the "coast" district, together with Cuero and Hallettsville from the "southwestern" district. These localities would seem to be more closely identified with the conditions of the coast district than with those of southwestern Texas so far as weevil conditions are concerned. For our present purposes, therefore, we have formed five groups of localities in Texas and one in western Louisiana. It is somewhat unfortunate that the limitations of the printed page prevent the association of all the data which should be considered in a study of this kind, and it is also realized that it is a difficult matter to make comparisons and to draw conclusions from a table even as extensive as is Table XI. We believe, however, that it is better to present these data, so that anyone who may care to study the subject more fully than can be done in this bulletin may have the opportunity of referring to these figures.

TABLE XI.—*Mortality in various classes of forms in six sections of area examined.*

WESTERN LOUISIANA.

Kind of forms examined, and locality.	Date.	Number of forms examined.	Weevil stages alive.				Weevil stages dead from heat or drying.			Mortality from heat, etc., by stages, per cent.			Killed by heat or drying.		Killed by ants.		Killed by parasites.		Total number of weevil stages found.	Total per cent of mortality from three causes.
					Adult.															
			Larva.	Pupa.	Present.	Emerged.	Larva.	Pupa.	Adult.	Larva.	Pupa.	Adult.	Number of stages.	Per cent of total stages found.	Number of stages.	Per cent of total stages found.	Number of stages.	Per cent of total stages found.		
Hanging, dried bolls:																				
Johnsons Bayou																				
Mansfield	Sept. 24–29	1,705	38	47	77	112	18	19	22	32.2	28.8	10.4	59	9.4	199	31.9	37	6.0	624	
Many	Aug. 23	1,250	43	103	84	117	25	21	32	36.8	17.0	13.7	78	14.5	53	10.0	32	6.0	539	
Orangeville																				
Total		2,955	81	150	161	229	43	40	54	34.7	21.0	12.2	137	11.8	252	21.7	69	6.0	1,163	39.4
Hanging, dried squares:																				
Johnsons Bayou																				
Mansfield	Aug. 24	435	1	2	5	61	27	13	10	96.4	86.7	13.2	50	20.3	119	48.4	7	2.8	246	
Many	Aug. 23	833	2	42	27	186	79	27	19	97.5	39.1	8.2	125	20.8	155	25.8	63	10.5	601	
Orangeville																				
Total		1,268	3	44	32	247	106	40	29	97.2	47.4	9.4	175	20.7	274	32.3	70	8.3	847	61.3
Fallen bolls:																				
Johnsons Bayou																				
Mansfield	Aug. 24–Sept. 29	1,222	40	17	13	30	28	5	1	41.2	22.8	2.3	34	16.1	77	36.5	0	0.0	211	
Many	Aug. 23	1,089	103	53	46	49	3	4	7	2.8	7.0	6.9	14	4.4	47	14.6	5	1.6	321	
Orangeville	Aug. 23–Sept. 30	295	13	8	9	11	2	2	2	13.3	20.0	9.0	6	9.0	17	25.4	0	0.0	67	
Total		2,506	156	78	68	90	33	11	10	17.5	12.4	6.0	54	9.0	141	23.5	5	0.8	599	33.4
Fallen squares:																				
Johnsons Bayou	Aug. 22–27	300	106	80	19	17	0	1	0	0.0	1.2	0.0	1	0.4	1	0.4	0	0.0	225	
Mansfield	Aug. 24–Sept. 29	962	36	31	12	104	46	18	6	56.1	36.7	4.9	70	14.6	218	45.3	2	0.4	481	
Many	Aug. 23	2,008	105	218	48	325	60	16	6	36.4	6.8	1.6	82	6.0	479	35.0	5	0.4	1,367	
Orangeville	Sept. 23–30	900	89	71	25	58	5	2	0	5.3	2.7	0.0	7	1.6	161	37.0	5	1.1	435	
Total, fallen squares		4,170	336	400	104	504	111	37	12	24.8	10.5	2.0	160	6.4	859	34.3	12	0.4	2,508	41.1
Total, fallen bolls		2,506	156	78	68	90	33	11	10	17.5	12.4	6.0	54	9.0	141	23.5	5	0.8	599	33.4
Total, hanging squares		1,268	3	44	32	247	106	40	29	97.2	47.4	9.4	175	20.7	274	32.3	70	8.3	847	61.3

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Total, hanging bolls		2,955	81	150	161	229	43	40	54	34.7	21.0	12.2	137	11.8	252	21.7	69	6.0	1,163	39.4
Total, all forms, western Louisiana		10,899	576	672	365	1,070	293	128	105	50.9	20.5	7.3	526	10.3	1,526	29.9	156	3.0	5,117	43.2

EASTERN TEXAS.

Hanging, dried bolls:																				
Marshall	Aug. 22	173	12	9	5	8	4	......	......	25.0	0.0	0.0	4	7.7	7	13.5	7	13.5	52	......
Overton	Aug. 23	210	9	15	8	10	4	2	1	30.8	11.8	5.3	7	7.9	32	36.0	4	4.5	89	......
Palestine	Aug. 10	510	77	46	23	27	6	0	0	7.2	0.0	0.0	6	2.8	8	3.8	7	3.3	211	......
Trinity	Aug. 9 and 30	1,330	64	59	17	45	7	2	3	9.9	3.3	4.6	12	4.5	27	10.0	28	10.4	269	......
Total		2,223	162	129	53	90	21	4	4	11.5	3.0	2.7	29	4.7	74	11.9	46	7.4	621	24.0
Hanging, dried squares:																				
Overton	Aug. 23	56	1	0	1	8	1	0	0	50.0	0.0	0.0	1	2.2	33	73.3	1	2.2	45	......
Palestine	Aug. 10	468	24	94	56	57	51	11	5	68.0	10.5	4.2	67	17.2	37	9.5	48	12.3	390	......
Trinity	Aug. 9 and 30	276	5	16	8	28	26	6	2	84.0	27.3	5.2	34	20.0	49	29.0	21	12.4	169	......
Total		800	30	110	65	93	78	17	7	72.2	13.4	4.2	102	17.0	119	19.7	70	11.6	604	48.2
Fallen bolls:																				
Marshall	Aug. 22	227	8	2	0	0	6	2	0	42.6	50.0	0.0	8	44.4	0	0.0	0	0.0	18	......
Overton	Aug. 23	375	29	9	5	0	4	0	0	12.1	0.0	0.0	4	4.7	44	48.4	0	0.0	91	......
Palestine	Aug. 10–Sept. 4	578	128	31	15	13	11	0	0	8.0	0.0	0.0	11	5.2	5	2.8	1	0.5	209	......
Trinity	Aug. 9 and 30	4,390	279	69	24	32	122	12	8	30.4	14.8	12.5	142	14.5	403	40.3	4	4.0	976	......
Total		5,570	444	111	44	45	143	14	8	24.4	11.2	8.2	165	12.8	452	36.2	5	0.4	1,294	49.4
Fallen squares:																				
Marshall	Aug. 22	52	7	4	1	0	3	0	1	30.0	0.0	50.0	4	17.4	7	30.4	0	0.0	23	......
Overton	Aug. 23	312	5	6	0	2	11	4	1	68.7	40.0	33.3	16	8.1	166	84.3	2	1.0	197	......
Palestine	Aug. 10–Sept. 4	1,335	323	408	62	75	131	24	1	29.0	55.6	0.7	156	14.9	6	0.6	14	1.3	1,048	......
Trinity	Aug. 9 and 30	2,641	403	115	34	92	105	13	2	20.7	10.2	1.6	120	7.7	641	41.3	18	1.2	1,552	......
Total, fallen squares		4,340	738	533	97	169	250	41	5	25.3	7.2	2.0	296	10.5	820	29.1	34	1.2	2,820	40.8
Total, fallen bolls		5,570	444	111	44	45	143	14	8	24.4	11.2	8.2	165	12.8	452	36.2	5	0.4	1,294	53.0
Total, hanging squares		800	30	110	65	93	78	17	7	72.2	13.4	4.2	102	17.0	119	19.7	70	11.6	604	48.2
Total, hanging bolls		2,223	162	129	53	90	21	4	4	11.5	3.0	2.7	29	4.7	74	11.9	46	7.4	621	24.0
Total, all forms, eastern Texas		12,933	1,374	883	259	397	492	76	24	35.8	8.6	3.7	592	11.1	1,465	27.4	155	2.9	5,339	41.4

TABLE XI.—*Mortality in various classes of forms in six sections of area examined*—Continued.

SOUTHERN TEXAS.

Kind of forms examined, and locality.	Date.	Number of forms examined.	Weevil stages alive.				Weevil stages dead from heat or drying.			Mortality from heat, etc., by stages, per cent.			Killed by heat or drying.		Killed by ants.		Killed by parasites.		Total number of weevil stages found.	Total per cent of mortality from three causes.
					Adult.															
			Larva.	Pupa.	Present.	Emerged.	Larva.	Pupa.	Adult.	Larva.	Pupa.	Adult.	Number of stages.	Per cent of total stages found.	Number of stages.	Per cent of total stages found.	Number of stages.	Per cent of total stages found.		
Hanging, dried bolls:																				
Cuero	Aug. 9-31	276	88	29	26	8	1	1	2	1.1	3.3	5.6	4	2.1	25	13.2	2	1.1	189	......
Goliad	Aug. 7-Sept. 3	530	81	53	52	32	1	3	......	1.2	5.4	0.0	4	1.5	20	7.5	13	5.0	265	......
Hallettsville	Aug. 9-30	1,240	71	67	61	24	19	2	1	21.1	2.9	1.2	22	8.1	16	5.8	11	4.0	273	......
Victoria	Sept. 1	315	68	27	30	16	12	2	5	15.0	6.9	9.8	19	9.5	48	23.9	1	0.5	201	......
Total		2,361	308	176	169	80	33	8	8	9.7	4.3	3.1	49	5.3	109	11.6	27	2.9	928	20.0
Hanging, dried squares:																				
Cuero	Aug. 9-31	931	97	60	40	16	85	4	1	46.7	6.2	1.7	90	20.6	32	7.3	87	20.0	438	......
Goliad	Aug. 7-Sept. 3	337	7	25	20	59	14	3	2	66.7	10.7	24.7	19	9.1	48	23.0	29	13.9	209	......
Hallettsville	Aug. 9-30	602	16	45	80	53	38	8	9	70.4	15.1	6.3	55	13.8	110	27.8	37	9.3	399	......
Victoria	July 2-Sept. 1	1,158	119	161	69	83	140	10	8	54.1	5.8	5.0	158	19.7	111	13.8	82	10.2	802	......
Total		3,028	239	291	209	211	277	25	20	53.7	8.0	4.5	322	17.3	301	16.3	235	12.7	1,848	47.0
Fallen bolls:																				
Beeville	July 12-Sept. 2	2,116	75	33	26	22	60	7	4	44.4	17.5	7.7	71	22.0	92	28.4	0	0.0	324	......
Brownsville	July 28-Sept. 5	1,820	69	59	69	107	18	2	8	20.7	3.3	4.3	28	7.3	24	6.3	13	3.7	384	......
Corpus Christi	July 10	321	8	8	2	1	1	0	0	11.1	0.0	0.0	1	5.0	0	0.0	0	0.0	20	......
Cuero	Aug. 31	282	16	10	0	3	18	6	2	53.0	37.5	40.0	26	32.5	25	31.3	0	0.0	80	......
Goliad	Sept. 3	488	64	29	8	11	9	1	1	12.3	3.3	5.0	11	8.3	5	3.8	3	2.3	133	......
Hallettsville	Aug. 30	902	11	2	2	4	18	5	4	62.1	71.4	40.0	27	29.0	46	49.5	1	1.1	93	......
Victoria	June 10-Sept. 1	2,351	171	53	6	3	17	9	0	9.0	14.5	0.0	26	9.2	19	6.8	0	0.0	281	......
Total		8,280	414	194	113	151	141	30	19	25.4	13.4	6.7	190	14.4	208	16.0	17	1.3	1,315	31.8
Fallen squares:																				
Beeville	July-Oct	3,312	83	70	31	69	422	71	18	83.2	50.0	15.3	511	19.2	1,774	67.1	36	13.2	2,644	......
Brownsville	July 28-Sept. 29	7,142	105	423	321	439	989	145	49	90.4	25.5	6.1	1,183	38.2	380	12.3	194	6.3	3,095	......
Corpus Christi	July 10	718	12	20	8	30	162	17	2	92.5	46.0	5.0	181	41.3	124	28.3	16	9.0	438	......
Cuero	Aug. 31	1,550	13	18	8	17	455	110	12	97.2	86.0	32.4	577	54.7	340	32.1	11	2.4	1,059	......

Goliad	Sept. 3	1,305	65	74	52	90	166	68	7	71.8	48.0	7.2	241	29.4	198	24.1	70	8.5	821	......
Hallettsville	Aug. 30	1,380	18	15	1	17	380	76	12	95.5	83.5	40.0	468	28.7	474	45.6	5	4.8	1,040	......
Victoria	June-Sept	8,004	1,054	384	121	303	1,787	53	8	62.2	12.1	1.9	1,848	28.5	2,010	31.0	200	3.1	6,488	......
Total, fallen squares		23,411	1,350	1,004	542	965	4,361	540	108	75.0	31.8	6.1	5,009	31.2	5,300	36.0	532	3.6	15,585	70.7
Total, fallen bolls		8,280	414	194	113	151	141	30	19	25.4	13.4	6.7	190	14.4	211	16.0	17	1.3	1,315	31.8
Total, hanging squares		3,028	239	291	209	211	277	25	20	53.7	8.0	4.5	322	17.3	301	16.3	235	12.7	1,848	47.0
Total, hanging bolls		2,361	308	176	169	80	33	8	8	9.7	4.3	3.1	49	5.3	109	11.6	27	2.9	9.28	20.0
Total, all forms, southern Texas		37,080	2,311	1,665	1,033	1,407	4,812	603	155	67.6	26.6	6.6	5,570	28.3	5,921	30.0	811	4.1	19,674	62.6

CENTRAL TEXAS.

Hanging, dried bolls:																				
Calvert	Aug. 22-Sept. 13	901	17	35	41	23	17	2	1	50.0	5.4	1.5	20	11.5	25	13.8	12	6.6	181	......
Corsicana	Aug. 23	1,250	29	40	26	44	14	0	0	32.6	0.0	0.0	14	8.0	13	7.4	6	3.4	176	......
Taylor	Aug. 16	125	20	11	1	3	0	0	0	0.0	0.0	0.0	0	0.0	2	5.0	1	2.5	40	......
Waco	July 25-Oct. 12	2,630	55	72	137	268	70	8	32	56.0	10.0	9.3	110	11.4	194	20.2	94	9.8	961	......
Total		4,906	121	158	205	338	101	10	33	45.5	6.0	5.7	144	10.4	234	17.2	113	8.4	1,358	28.8
Hanging, dried squares:																				
Calvert	Aug. 22-Sep. 13	207	6	5	2	11	21	3	0	74.1	37.5	0.0	24	29.6	20	24.7	8	9.9	81	......
Corsicana	Aug. 23	125	4	9	7	12	18	2	2	81.8	18.2	9.5	22	25.9	19	22.4	12	14.1	85	......
Taylor	Aug. 16	116	21	23	12	3	7	2	0	25.0	8.0	0.0	9	11.4	2	2.5	8	10.1	79	......
Waco	July 25-Oct. 12	928	9	23	6	78	113	3	9	92.6	11.5	9.7	125	27.1	87	18.9	126	27.3	461	......
Total		1,376	40	60	27	104	159	10	11	80.0	14.3	7.1	180	25.5	128	18.1	154	21.8	706	65.4
Fallen bolls:																				
Calvert	Aug. 28-Sept. 13	913	203	113	9	2	2	1	0	1.0	0.9	0.0	3	0.9	4	1.2	0	0.0	347	......
Corsicana	Sept. 18	310	2	1	0	3	9	8	3	81.8	88.9	50.0	20	58.5	4	11.8	2	5.9	34	......
Taylor	Aug. 16	310	21	8	0	1	0	0	0	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0	34	......
Waco	July 25-Oct. 12	2,933	110	43	15	31	27	23	19	20.0	34.8	29.0	69	18.1	98	25.7	7	1.8	381	......
Total		4,466	336	165	24	37	38	32	22	10.2	16.2	26.5	92	11.6	106	13.3	9	1.1	796	26.0
Fallen squares:																				
Calvert	Aug. 28-Sept. 13	1,386	88	349	132	93	9	7	1	9.2	2.0	0.4	17	1.6	105	10.0	15	1.5	1,039	......
Corsicana	Sept. 18	26	1	0	0	1	3	1	0	75.0	100.0	0.0	4	25.0	10	62.5	0	0.0	16	......
Taylor	Aug. 16	246	74	38	8	3	27	0	0	26.7	0.0	0.0	27	17.0	0	0.0	1	0.7	153	......
Waco	July 25-Oct. 12	4,318	205	153	66	110	483	71	38	70.2	31.7	17.8	592	34.2	554	32.0	151	8.8	1,731	......
Total, fallen squares		5,976	368	540	206	207	522	79	39	58.6	12.7	8.6	640	21.7	669	22.7	167	5.7	2,939	50.0
Total, fallen bolls		4,466	336	165	24	37	38	32	22	10.2	16.2	26.5	92	11.6	106	13.3	9	1.1	796	26.0
Total, hanging bolls		4,906	121	158	205	338	101	10	33	45.5	6.0	5.7	144	10.4	234	17.2	113	8.4	1,358	28.8

TABLE XI.—*Mortality in various classes of forms in six sections of area examined*—Continued.

CENTRAL TEXAS—Continued.

Kind of forms examined, and locality.	Date.	Number of forms examined.	Weevil stages alive.				Weevil stages dead from heat or drying.			Mortality from heat, etc., by stages, per cent.			Killed by heat or drying.		Killed by ants.		Killed by parasites.		Total number of weevil stages found.	Total per cent of mortality from three causes.
			Larva.	Pupa.	Adult. Present.	Adult. Emerged.	Larva.	Pupa.	Adult.	Larva.	Pupa.	Adult.	Number of stages.	Per cent of total stages found.	Number of stages.	Per cent of total stages found.	Number of stages.	Per cent of total stages found.		
Total, hanging squares		1,386	40	60	27	104	159	10	11	80.0	14.3	7.1	180	25.5	128	18.1	154	21.8	706	65.4
Total, all forms, central Texas		16,734	865	923	462	686	820	131	105	48.7	12.4	8.4	1,056	18.2	1,137	19.8	443	7.8	5,799	45.5
NORTHEASTERN TEXAS.																				
Hanging, dried bolls:																				
Dallas	Aug. 29-Oct. 15	4,604	144	243	239	255	38	11	18	20.9	4.3	3.5	67	4.9	232	17.0	67	4.9	1,362	26.9
Hanging, dried squares:																				
Dallas	Aug. 29-Oct. 6	225	5	13	7	41	18	0	0	78.3	0.0	0.0	18	16.4	19	17.3	9	8.2	110	41.8
Fallen bolls:																				
Dallas	Aug. 29	367	51	10	0	0	0	0	0	0.0	0.0	0.0	0	0.0	9	12.9	0	0.0	70	......
Fullers	Aug. 17	382	3	0	0	1	0	0	0	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0	4	......
Mineola	Oct. 2	158	21	12	2	0	6	5	3	22.2	29.4	60.0	14	24.6	7	12.3	1	1.8	57	......
Terrell	Sept 19	220	30	11	1	0	0	0	0	0.0	0.0	0.0	0	0.0	3	6.5	0	0.0	46	......
Total		1,127	105	33	3	1	6	5	3	5.4	13.2	42.9	14	8.0	19	10.7	1	0.6	177	19.3
Fallen squares:																				
Dallas	Aug. 29	111	14	8	0	7	2	0	0	12.5	0.0	0.0	2	3.6	23	42.6	0	0.0	54	......
Fullers	Aug. 17	100	20	0	0	1	0	0	0	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0	21	......
Mineola	Aug. 10-Oct. 2	917	116	60	7	26	72	61	11	38.3	50.0	30.0	144	32.4	83	18.7	9	2.0	445	......
Terrell	Sept. 19	88	26	19	2	3	1	0	0	3.7	0.0	0.0	1	1.9	0	0.0	0	0.0	53	......
Total, fallen squares		1,216	176	87	9	37	75	61	11	30.0	41.2	20.0	147	25.2	106	18.2	9	1.5	573	44.9

Total, fallen bolls		1,127	105	33	3	1	6	5	3	5.4	13.2	42.9	14	8.0	10	10.7	1	0.6	177	19.3
Total, hanging squares		225	5	13	7	41	18	0	0	78.3	0.0	0.0	18	16.4	19	17.3	9	8.2	110	41.8
Total, hanging bolls		4,604	144	243	239	255	38	11	18	20.9	4.3	3.5	67	4.9	232	17.0	67	4.9	1,362	26.9
Total, all forms, northeastern Texas		7,172	430	376	258	334	137	77	32	24.2	17.0	5.1	246	11.1	376	16.9	86	3.9	2,222	31.9
SOUTHWESTERN TEXAS.																				
Hanging, dried bolls:																				
San Antonio		310	0	0	0	0	0	0	0	0.0	0.0	0.0	0	0.0	1	100.0	0	0.0	1	100.0
Hanging, dried squares.																				
Roosevelt	Sept. 25	216	20	19	5	10	6	1	0	23.1	5.0	0.0	7	8.6	18	22.2	2	2.5	81	......
San Antonio	Aug. 15	91	8	0	0	2	0	0	0	0.0	0.0	0.0	0	0.0	24	70.6	0	0.0	34	......
Total		307	28	19	5	12	6	1	0	21.4	5.0	0.0	7	6.1	42	36.5	2	1.7	115	44.3
Fallen bolls:																				
Junction	Sept. 24	44	5	2	0	1	3	0	0	37.0	0.0	0.0	3	17.6	5	29.4	1	6.0	17	......
Kerrville	Aug. 26–Sept. 4	500	215	41	10	2	9	0	0	4.0	0.0	0.0	9	3.1	7	1.4	7	1.4	295	......
Lula	Sept. 26	46	26	11	1	0	0	0	0	0.0	0.0	0.0	0	0.0	7	13.7	0	0.0	51	......
Roosevelt	Sept. 24	46	59	8	1	1	0	0	0	0.0	0.0	0.0	0	0.0	3	4.1	0	0.0	74	......
Total		636	305	62	12	4	12	0	0	3.8	0.0	0.0	12	2.7	22	5.0	8	1.8	437	9.6
Fallen squares:																				
Junction	Sept. 24	383	11	10	2	22	33	1	3	75.0	9.1	11.1	37	28.7	33	25.6	11	8.5	129	......
Kerrville	Aug. 20–Sept. 3	46	14	10	0	0	1	0	0	6.7	0.0	0.0	1	3.0	6	17.1	4	11.4	35	......
Lula	Sept. 26	278	22	12	6	3	2	0	0	8.3	0.0	0.0	2	3.6	3	5.6	0	0.0	54	......
Roosevelt	Sept. 24	88	16	13	5	7	8	1	0	33.3	7.1	0.0	9	13.0	10	14.5	9	13.0	69	......
Total, fallen squares		795	63	45	13	32	44	2	3	41.1	4.3	6.2	49	17.0	52	18.1	24	8.5	287	43.6
Total, fallen bolls		636	305	62	12	4	12	0	0	3.8	0.0	0.0	12	2.7	22	5.0	8	1.8	437	9.6
Total, hanging squares		307	28	19	5	12	6	1	0	21.4	5.0	0.0	7	6.1	42	36.5	2	1.7	115	44.3
Total, hanging bolls		310	0	0	0	0	0	0	0	0.0	0.0	0.0	0	0.0	1	100.0	0	0.0	1	100.0
Total, all forms, southwestern Texas		2,048	396	126	30	48	62	3	3	13.5	2.3	3.7	68	8.1	117	13.9	34	4.0	840	26.0

A casual examination of the data given in Table XI will be sufficient to show that considerable variation exists in the mortality produced by each factor in the same class of forms in even the most closely associated localities. This seems to prove the influence of local conditions affecting the mortality produced by the different factors. From several considerations this would seem to be an encouraging fact, indicating that it may be possible to change unfavorable conditions or to take advantage of those which are most favorable in regard to environment, cultivation, soil, etc. It is noticeable that in all classes of forms, in practically all localities, a large proportion of the mortality from heat occurs during the larval stage. In southern Texas alone does the larval mortality in hanging dried squares fall below that in any other class of forms. In that case three-fourths of all larvæ found in fallen squares were killed by heat, while in the hanging squares slightly more than one-half were thus killed. As a general average for the entire area about 53 per cent of the larvæ, 18 per cent of the pupæ, and 6 per cent of the adults had been killed by heat. These percentages are very nearly in the ratio of nine, three, and one. It appears that the nearer the weevil stage approaches maturity the less susceptible is it to the adverse influence of heat or drying. This shows how important it is that the spacing of the plants be such as will submit the largest possible proportion of fallen forms to the direct influence of sunshine. Whatever spacing may have been found advisable where weevils were not present, there can now be no question about the general soundness of the recommendation for increasing the space allowed each plant wherever the weevil is present in abundance. It is true that the efficiency of this factor under similar cultural conditions may vary widely during different seasons, and during different portions of the same season, but in any case the data given would seem sufficiently reliable to prove that under nearly all conditions, with the weevil present, wide spacing is advantageous.

It was found impracticable to determine the effect of ant attack upon the various stages of the weevil. It may be stated that, in general, parasites were found to attack the weevil during the last few days of the larval stage. A considerable number of parasitized pupæ were found, and in a very few cases the weevil had become adult before death was caused by the parasite. As the parasite causes the death of its host very quickly after beginning its attack, the time required for the egg stage of the parasite should be taken into consideration in determining the time of attack, but it has been impossible, as yet, to determine the egg stage for any of the parasites of the weevil.

MORTALITY IN EACH CLASS OF FORMS FOR EACH SECTION.

Some additional points in the comparison of the general results shown in Table XI may be more conveniently shown by such arrangement of the totals and average percentages as is given in Table XII.

TABLE XII.—*Comparison of mortality results by class of forms and section of State.*

Class of fruit and section of State.	Total number of forms examined.	Total number of stages found.	Total number of stages destroyed.			Mortality percentage.			Total mortality—three factors.	Rank of section by total mortality.
			Heat.	Ants.	Parasites.	Heat.	Ants.	Parasites.		
Dried hanging bolls:						*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	
Western Louisiana	2,955	1,163	137	252	69	11.8	21.7	6.0	39.4	2
Eastern Texas	2,223	621	29	74	46	4.7	11.9	7.4	24.0	5
Southern Texas	2,361	928	49	109	27	5.3	11.6	2.9	20.0	6
Central Texas	4,906	1.358	144	234	113	10.4	17.2	8.4	28.8	3
Northern Texas	4,604	1,362	67	232	67	4.9	17.0	4.9	26.9	4
Southwestern Texas	310	1	0	1	0	0.0	100.0	0.0	100.0	1
	17,359	5,433	426	902	322	7.8	16.6	6.0	30.4	....
Dried hanging squares:										
Western Louisiana	1,268	847	175	274	70	20.7	32.3	8.3	61.3	2
Eastern Texas	800	604	102	119	70	17.0	19.7	11.3	48.2	3
Southern Texas	3,028	1,848	322	301	235	17.3	16.3	12.7	47.0	4
Central Texas	1,376	706	180	128	154	25.5	18.1	21.8	65.4	1
Northern Texas	225	110	18	19	9	16.4	17.3	8.2	41.8	6
Southwestern Texas	307	115	7	42	2	6.1	36.5	1.7	44.3	5
	7,004	4.230	804	883	540	19.0	20.9	12.8	52.6	....
Fallen bolls:										
Western Louisiana	2,606	599	54	141	5	9.0	23.5	0.8	33.4	2
Eastern Texas	5,570	1,294	165	452	5	12.8	36.2	4.0	50.0	1
Southern Texas	8,280	1,315	190	211	17	14.4	16.0	1.3	31.8	3
Central Texas	4,466	796	92	106	9	11.6	13.3	1.1	26.0	4
Northern Texas	1,127	177	14	19	1	8.0	10.7	0.6	19.2	5
Southwestern Texas	636	437	12	22	8	2.7	5.0	1.8	9.6	6
	22,685	4,618	527	951	45	11.4	21.0	1.0	33.4	....
Fallen squares:										
Western Louisiana	4,170	2,508	160	859	12	6.4	34.2	0.4	43.0	5
Eastern Texas	4,340	2,820	296	820	34	10.5	39.1	1.2	40.8	6
Southern Texas	23,411	15,583	5,009	5,280	532	31.2	36.0	3.6	70.7	1
Central Texas	5,976	2,939	640	669	167	21.7	22.7	5.7	50.0	2
Northern Texas	1,216	573	147	106	9	25.2	18.2	1.5	44.9	3
Southwestern Texas	795	287	49	52	24	17.0	18.1	8.5	43.6	4
	39,908	24,710	6,301	7,786	778	25.5	32.8	3.3	60.8	....

In Table XII one of the most striking points is the rather uniformly high percentage of parasitism in each section found in dried hanging bolls and squares. By far the highest percentage of parasitism is the 21.8 per cent shown in dried squares in central Texas. Western Texas leads in the percentage of parasitism in fallen squares, but when the comparatively small number (287) of weevil stages found is considered, it would appear that 8.5 per cent may be largely in excess of the percentage which would have been found in so extensive a series of observations as was made in central or southern Texas. A similar exception should be noted for the 100 per cent of mortality from ant work in dried hanging bolls in western Texas where only a single weevil stage was found. In dried hanging squares the mortality from heat, as a general rule, very nearly equals that from ant attack, while in other classes of forms ants destroyed many more stages of the weevil than did heat and parasites together.

In regard to ant work, it is evident that the high percentage shown among fallen squares in each of the six sections examined is very important. This is especially so because of the fact that these percentages apply to the largest series of examinations made, the number of weevil stages found in this class of forms being somewhat more than 60 per cent of the total. Eastern Texas, southern Texas, and western Louisiana seem to have profited most by the work of the ants in fallen squares, and these same sections show the highest percentages of ant work in fallen bolls, as might naturally be expected.

The wide diversity of conditions under which the ants successfully attack the weevil is another one of the encouraging features shown by this work. It proves in a very reassuring way the general distribution of this species of Solenopsis and their activity in destroying weevil stages in every class of forms and in all parts of the infested area. The value of the work which they do in restraining the weevil multiplication can not be estimated. Their work henceforth will be more fully appreciated and a careful study will be made of the life history of the species and of the possibility of producing an increase in its efficiency.

SECTIONS PROFITING MOST BY NATURAL CONTROL.

Still another arrangement of this same series of results will show most plainly a comparison of the total mortality in the four classes of forms for each of the six sections into which the localities have been grouped. In Table XIII are shown the general results of the examinations.

TABLE XIII.—*Comparison of total mortality results according to section.*

Section.	Total forms examined.	Weevil stages alive.				Weevil stages dead from heat or drying.			Mortality from heat, etc., by stages.		
		Larva.	Pupa.	Adult.		Larva.	Pupa.	Adult.	Larva.	Pupa.	Adult.
				Present.	Emerged.						
									Per ct.	*P. ct.*	*Per ct.*
Western Louisiana	10,999	576	672	365	1,070	293	138	105	50.9	20.5	7.3
Eastern Texas	12,933	1,374	883	259	397	492	76	24	35.8	8.6	3.7
Southern Texas	37,080	2,311	1,665	1,033	1,407	4,812	603	155	67.6	26.6	6.0
Central Texas	16,724	865	923	462	686	820	131	105	48.7	12.4	8.4
Northeastern Texas	7,172	430	376	258	334	137	77	32	24.2	17.0	5.1
Southwestern Texas	2,048	396	126	30	48	62	3	3	1.6	2.4	3.8
	86,956	5,952	4,645	2,407	3,942	6,616	1,018	424	52.6	18.0	6.3

Section.	Killed by heat or drying.		Killed by ants.		Killed by parasites.		Total number of weevil stages found.	Total per cent of mortality from three causes.	Rank of section in percentage of mortality.
	Number of stages.	Per cent of total stages found.	Number of stages.	Per cent of total stages found.	Number of stages.	Per cent of total stages found.			
Western Louisiana	526	10.3	1,526	29.9	156	3.0	5,117	43.2	3
Eastern Texas	592	11.1	1,465	27.4	155	2.9	5,339	41.4	4
Southern Texas	5,570	28.3	5,921	30.0	811	4.1	19,674	62.6	1
Central Texas	1,056	18.2	1,137	19.8	443	7.8	5,799	45.5	2
Northeastern Texas	246	11.1	376	16.9	86	3.9	2,222	31.9	5
Southwestern Texas	68	8.1	117	13.9	34	4.0	840	26.0	6
	8,058	20.7	10,542	27.0	1,685	4.3	38,991	52.0	......

Many of the conclusions which might be drawn from Table XIII have already been stated in connection with preceding tables. The last column shows that southern Texas enjoys the benefits of natural control to a larger degree than does any other section. In that section 62.6 per cent (nearly two-thirds) of all stages found had been destroyed. One half of this mortality was accomplished by ants, the other half by heat and parasites combined. Central Texas stands next, with a total mortality of 45.5 per cent. In this section, while the effectiveness of heat and of ants had decreased, that of parasites had considerably increased. The increase in parasite attack, however, was by no means sufficient to counterbalance the decrease from the other two factors. Western Louisiana and eastern Texas, with 43.2 and 41.4 per cent of total mortality, respectively, show very close agreement in the proportions of mortality from each factor. This close agreement might be anticipated because of the similarity in soil, climatic, and cultural conditions prevailing in those adjacent sections. The principal reason for separating the localities into these two sections was to facilitate a comparison of the recently infested territory of Louisiana with the older-infested sections of Texas. In this respect, also, but little difference exists between eastern Texas and western Louisiana. In analyzing the factors producing the closely similar total percentages of mortality in western Louisiana and in central Texas it will be seen that there were very essential differences. In western Louisiana nearly 70 per cent of the total mortality found was due to ant attack, while in central Texas only 43.5 per cent was due to ants. It is evident that in central Texas may be found the conditions which are most favorable to parasite attack. An extended study is being made of the entire field of parasitic attack upon the boll weevil, and part of the results previously obtained may be found in Bulletin 73 of this Bureau. By far the lowest proportion of total mortality is that found for southwestern Texas. Most of the localities included in this section have but recently become infested. It would appear, however, that in the higher altitude of those localities heat may not be quite as effective and that ants may not be as abundantly distributed as they are in other sections of the State. The observations in this locality have not extended over a sufficient period to justify any general conclusions regarding the result of the smaller degree of natural control which would appear from the observations made. It is quite possible that other factors than these which are here considered may serve to check the weevil in this section. Such a condition as a much larger mortality during the hibernation period might hold the weevils largely in check in spite of the smaller mortality during the summer.

DESTRUCTION OF COTTON FORMS BY WEEVIL ATTACK OR BY NATURAL CAUSES.

It seems advisable in connection with this study of factors concerned in the natural control of the boll weevil to place on record some of the data which have been obtained, showing the proportion of squares and bolls which have been found to be destroyed by weevil attack or which were shed by the plant from natural causes without insect injury.

COLLECTIONS OF FALLEN FORMS IN 1905.

During the season of 1905 quite extensive experiments were made to determine the value of a thorough collection of fallen forms in checking the injury done by the weevil. These experiments showed a net loss. The cost of collecting fallen forms exceeded by several dollars per acre the slight increase in yield shown by the plots from which collections were made as compared with plots under similar conditions, but in which no forms were collected. No examinations were made of these forms to determine the proportion which had been attacked by the weevil, but from sample lots as shown in Table XIV the proportion of squares and bolls was determined.

TABLE XIV.—*Proportion of squares and bolls among fallen fruit, Texas, 1905.*

Locality.	Date.	Total forms examined.	Squares.		Bolls.	
			Number.	Per cent of total.	Number.	Per cent of total.
Gurley, Tex	Aug. 10–12	498	147	29.5	351	70.5
Do	Aug. 17	2,442	411	16.8	2,031	83.2
Do	Aug. 19	775	239	30.8	536	69.2
Do	Aug. 31	650	240	36.9	410	63.1
Quinlan, Tex	Aug. 24	2,542	472	18.6	2,070	81.4
Waco Tex	Aug. 31	4,036	1,269	31.4	2,767	68.6
Total or average		10,943	2,778	25.4	8,165	74.6

It should be stated that the lots for which figures are given in Table XIV were from the last collections made in those experiments. The picking began early in July, and doubtless a test at that time would have shown a considerably larger proportion of squares. As it was, the average proportion among the nearly 11,000 forms examined was approximately one square to every three small bolls. In the field at Gurley five collections were made in about six weeks. This work extended over one-half of the 16-acre field. Upon this 8 acres about 730,000 fallen forms were collected. According to the proportions shown in Table XV, it would seem conservative to estimate that in this field at Gurley there were collected fallen squares containing from 100,000 to 125,000 weevil stages, and in the fallen bolls from 100,000 to 115,000 stages. From this 8 acres, therefore, there were collected, during July and August, 1905, in all probability from 200,000 to 250,000 weevil stages. If we apply to this number of stages the proportion shown by Table VI to have reached the adult stage in Louisiana and Texas in 1906 (i. e., about 17 per cent), it would appear that this work of collection prevented the emergence of from 34,000 to 42,500 adult weevils upon an area of 8 acres. When it is considered that in spite of this large destruction of weevils the resulting increase in yield averaged hardly 50 pounds of cotton per acre, the reader will be able to realize more clearly than he could without such a comparison the tremendous importance of the factors of natural control which do, under exceptionally favorable conditions, make it possible to produce a very profitable crop, because of their direct effect in reducing the number of weevils which reach maturity. It will be understood, also, that the total mortality resulting from all factors must become very large indeed in order to reduce the damage done by the small percentage which do survive, so that the development of the crop may far outstrip the insect attack.

COLLECTIONS OF FALLEN AND OF DRIED HANGING FORMS IN 1906.

In Tables XV and XVI are presented some of the results from the work of 1906. In these tables, however, it is possible to include a statement of the number of weevil stages found in each examination. In the collection of this material there was no particular selection of squares or bolls, but all forms were taken as they occurred. Special collections were made, however, for hanging and for fallen forms, so that the proportion of hanging and of fallen forms could not be considered as an indication of the proportion which actually existed upon the area from which collections were made. This explanation applies both to Table XV and to Table XVI.

TABLE XV.—*Proportion of fruit destroyed by insect injury or by natural causes, Louisiana, 1906.*

Class of fruit examined, and locality.	Date.	Total examined.	Weevil stages not found.		Infested by weevil.		
			Number of forms.	Per cent of total examined.	Number.	Per cent of total.	Total weevil stages found.
Fallen bolls:							
Mansfield	Aug. 24	450	392	87.1	58	12.9	58
Mansfield	Aug. 24	400	300	75.0	100	25.0	106
Mansfield	Sept. 29	372	332	89.2	40	10.8	47
Many	Aug. 23	555	402	72.4	153	27.6	153
Many	Aug. 23	534	396	74.2	138	25.8	168
Orangeville	Aug. 23	145	109	75.2	36	24.8	36
Orangeville	Sept. 30	150	119	79.3	31	20.7	31
Totals, fallen bolls		2,606	2,050	78.7	556	21.3	599
Fallen squares:							
Johnsons Bayou	Aug. 22-27	300	78	26.0	222	74.0	225
Mansfield	Aug. 24	400	193	48.25	207	51.75	207
Mansfield	Aug. 24	525	268	51.0	257	49.0	257
Mansfield	Sept. 29	37	20	54.1	17	45.9	17
Many	Aug. 23	875	336	38.4	539	61.6	539
Many	Aug. 23	1,133	407	35.9	726	64.1	728
Orangeville	Aug. 23	400	142	35.5	258	64.5	259
Orangeville	Aug. 23	500	332	66.4	168	33.6	176
Totals, fallen squares		4,170	1,776	42.6	2,394	57.4	2,408

TABLE XV.—*Proportion of fruit destroyed by insect injury or by natural causes, Louisiana, 1906*—Continued.

Class of fruit examined, and locality.	Date.	Total examined.	Weevil stages not found.		Infested by weevil.		
			Number of forms.	Per cent of total examined.	Number.	Per cent of total.	Total weevil stages found.
Hanging bolls:							
Mansfield	Aug. 24	1,412	965	68.3	447	31.7	479
Mansfield	Sept. 29	293	190	64.8	103	35.2	145
Many	Aug. 23	125	74	59.2	51	40.8	54
Many	Aug. 23	800	450	56.3	350	43.7	380
Many	Aug. 23	325	228	70.2	97	29.8	105
Totals, hanging bolls		2,955	1,907	64.2	1,048	35.8	1,163
Hanging squares:							
Mansfield	Aug. 24	430	186	43.3	244	56.7	244
Mansfield	Sept. 29	5	3	60.0	2	40.0	2
Many	Aug. 23	115	27	23.5	88	76.5	88
Many	Aug. 23	466	136	29.2	330	70.8	330
Many	Aug. 23	252	69	27.4	183	72.6	183
Totals, hanging squares		1,268	421	33.2	847	66.8	847
Totals, all forms		10,999	6,154	56.0	4,845	44.0	5,017

As is shown in the last line of totals, giving the average percentages for the four classes of forms examined, 56 per cent of the 11,000 forms contained no stage of the weevil. Among 5,561 bolls, including both hanging and fallen bolls, 71 per cent contained no weevil stage, while in the remaining 29 per cent, 1,604 bolls, there were 1,762 weevil stages. This means that in the bolls found to contain weevil stages there were an average of 1.098 stages per boll. Among the 5,438 squares, 40 per cent contained no weevil stage. In the 3,241 squares containing stages there were 3,255 found. In squares, therefore, there were about 1.004 stages for each square. This shows how strictly the multiplication of the weevil is limited by the available supply of squares. An average of squares and bolls shows but 1.035 weevil stages for each form which was found to contain them. Among all bolls but 30 per cent contained a weevil stage, while among all squares 60 per cent were infested. While it is probable that few of the 30 per cent of squares which failed to show some stage of the weevil had really escaped all form of weevil injury, it is equally probable that a very small portion of the 70 per cent of bolls which were found to contain no stage of the weevil had ever been attacked in any way. Thus, while few squares perished regardless of weevil attack, probably more than one-half of all the small bolls which perished had not been attacked in any way by the weevil, though it is possible that in many cases there had been some form of injury to the square or bloom connected with that boll.

In the examination of material from Texas there are so many localities represented for each class of forms that it seems advisable to divide the table into a section for each class.

TABLE XVI.—*Proportion of fruit destroyed by insect injury or by natural causes, Texas, 1906.*

A. HANGING, DRIED BOLLS.

Date.	Locality.	Total bolls examined.	Bolls without weevil stages.		Bolls with weevil stages.		
			Number.	Per cent of total.	Number.	Per cent of total.	Number of weevil stages found.
Aug. 22	Calvert	208	192	92.1	16	7.9	16
Aug. 28	Calvert	311	246	79.1	65	20.9	70
Aug. 31	Calvert	157	137	87.3	20	12.7	20
Sept. 13	Calvert	225	170	75.8	55	24.2	75
Aug. 23	Corsicana	450	391	82.4	59	17.6	59
Aug. 23	Corsicana	800	675	84.4	125	15.6	117
Aug. 9	Cuero	26	20	76.9	6	23.1	6
Aug. 31	Cuero	250	138	55.2	112	44.8	183
Aug. 29	Dallas	232	206	88.8	26	11.2	26
Sept. 12	Dallas	511	408	80.0	103	20.0	103
Sept. 13	Dallas	571	475	83.2	96	16.8	107
Oct. 2	Dallas	450	358	80.0	92	20.0	95
Oct. 2	Dallas	323	220	68.3	103	31.7	157
Oct. 6	Dallas	498	344	69.1	154	30.9	190
Oct. 6	Dallas	505	389	77.0	116	33.0	125
Oct. 6	Dallas	510	425	83.3	85	16.7	96
Oct. 6	Dallas	494	354	71.1	140	38.9	216
Oct. 15	Dallas	510	430	84.3	80	15.7	247
Aug. 7	Goliad	165	132	80.0	33	20.0	33
Sept. 3	Goliad	125	68	54.4	57	45.6	103
Sept. 3	Goliad	240	111	46.2	129	53.8	129
Aug. 9	Hallettsville	370	274	74.1	96	25.9	96
Aug. 30	Hallettsville	870	700	80.0	170	20.0	177
Aug. 22	Marshall	173	133	76.9	40	23.1	52
Aug. 23	Overton	210	121	57.6	89	42.4	89
Aug. 10	Palestine	510	299	58.6	211	41.4	211
Sept. 25	Roosevelt	9	6	66.7	3	33.3	9
Aug. 15	San Antonio	75	74	98.7	1	1.3	1
Aug. 16	Taylor	125	85	68.0	40	32.0	40
Aug. 9	Trinity	605	463	76.5	142	23.5	142
Aug. 30	Trinity	725	603	83.2	122	16.8	127
Sept. 1	Victoria	315	157	50.0	158	50.0	201
July 25	Waco	434	412	95.0	22	5.0	22
Aug. 17	Waco	160	144	90.0	16	10.0	16
Aug. 28	Waco	795	613	77.1	182	22.9	252
Aug. 29	Waco	370	243	65.7	127	34.3	153
Sept. 19	Waco	29	17	58.6	12	41.4	12
Sept. 19	Waco	200	144	72.0	56	38.0	66
Sept. 19	Waco	34	18	53.0	16	47.0	16
Sept. 20	Waco	169	109	64.5	60	35.5	79
Sept. 20	Waco	100	17	17.0	83	83.0	112
Oct. 12	Waco	339	170	50.0	169	50.0	233
Total.		14,178	10,691	75.4	3,487	24.6	4,279

Table XVI.—*Proportion of fruit destroyed by insect injury or by natural causes, Texas, 1906*—Continued.

B. HANGING, DRIED SQUARES.

Date.	Locality.	Total squares examined.	Squares without weevil stages.		Squares with weevil stages.		
			Number.	Per cent of total.	Number.	Per cent of total.	Number of weevil stages present.
Aug. 22	Calvert	103	97	94.2	6	5.8	6
Aug. 28	Calvert	62	14	22.6	48	77.4	48
Aug. 31	Calvert	18	4	22.2	14	77.8	14
Sept. 13	Calvert	24	13	54.2	11	45.8	13
Aug. 23	Corsicana	72	18	25.0	54	75.0	55
Aug. 23	Corsicana	53	23	43.4	30	56.6	30
Aug. 9	Cuero	106	15	14.2	91	85.8	91
Aug. 31	Cuero	825	481	58.3	344	41.7	347
Aug. 29	Dallas	61	47	77.5	14	22.5	12
Sept. 12	Dallas	31	17	54.8	14	45.2	14
Sept. 13	Dallas	100	36	36.0	64	64.0	64
Oct. 2	Dallas	11	3	27.3	8	72.7	8
Oct. 6	Dallas	8	5	62.5	3	37.5	3
Oct. 6	Dallas	5	1	20.0	4	80.0	4
Oct. 6	Dallas	9	4	44.4	5	55.6	5
Aug. 7	Goliad	35	12	34.3	23	65.7	23
Sept. 3	Goliad	152	68	44.7	84	55.3	84
Sept. 3	Goliad	150	48	32.0	102	68.0	102
Aug. 9	Hallettsville	122	37	30.0	85	70.0	85
Aug. 30	Hallettsville	480	167	34.8	313	65.2	314
Aug. 22	Marshall	12	8	66.7	4	33.3	5
Aug. 23	Overton	56	11	19.6	45	80.4	45
Aug. 10	Palestine	468	78	16.7	390	83.3	390
Sept. 25	Roosevelt	216	136	63.0	80	37.0	81
Aug. 15	San Antonio	6	5	81.7	1	18.3	1
Aug. 16	Taylor	116	37	32.0	79	68.0	81
Aug. 9	Trinity	216	78	36.1	138	63.9	138
Aug. 30	Trinity	60	29	48.3	31	51.7	31
Sept. 1	Victoria	938	293	31.2	645	68.8	654
July 2	Victoria	220	82	37.3	138	62.7	148
July 25	Waco	254	155	61.0	99	39.0	99
Aug. 17	Waco	54	32	59.3	22	40.7	22
Aug. 28	Waco	213	75	35.2	138	64.8	138
Aug. 29	Waco	200	108	54.0	92	46.0	92
Sept. 19	Waco	20	7	35.0	13	65.0	13
Sept. 19	Waco	43	27	62.8	16	37.2	16
Sept. 19	Waco	11	9	81.7	2	18.3	4
Sept. 20	Waco	90	35	38.9	55	61.1	55
Sept. 20	Waco	43	19	44.2	24	55.8	24
Total		5,663	2,334	41.2	3,329	58.8	3,359

TABLE XVI.—*Proportion of fruit destroyed by insect injury or by natural causes, Texas, 1906*—Continued.

C. FALLEN BOLLS.

Date.	Locality.	Total bolls examined.	Bolls without weevil stages.		Bolls with weevil stages.		
			Number.	Per cent of total.	Number.	Per cent of total.	Number of weevil stages found.
July 12	Beeville	140	131	93.6	9	6.4	9
Aug. 8	Beeville	78	59	75.6	19	24.4	19
Aug. 13	Beeville	310	278	90.0	32	10.0	32
Sept. 3	Beeville	1,588	1,328	83.6	260	16.4	264
July 28	Beeville	35	30	85.7	5	14.3	5
Sept. 5	Beeville	1,785	1,428	80.0	357	20.0	379
Aug. 28	Calvert	573	469	85.3	104	14.7	107
Sept. 13	Calvert	340	173	50.9	167	49.1	240
July 10	Corpus Christi	321	301	93.8	20	6.2	20
Sept. 18	Corsicana	310	277	89.4	33	10.6	34
Aug. 31	Cuero	282	219	77.7	63	22.3	80
Aug. 29	Dallas	367	327	89.1	40	10.9	70
Aug. 17	Fullers	382	378	99.0	4	1.0	4
Sept. 3	Goliad	133	104	78.2	29	21.8	44
Sept. 3	Goliad	355	280	80.0	75	20.0	89
Aug. 30	Hallettsville	540	469	86.9	71	13.1	79
Aug. 30	Hallettsville	362	349	96.4	13	3.6	14
Sept. 24	Junction	44	28	63.6	16	36.4	17
Aug. 26	Kerrville	232	132	56.9	100	43.1	100
Sept. 3	Kerrville	268	136	50.1	132	49.9	195
Sept. 26	Lula	46	19	41.3	27	58.7	51
Aug. 22	Marshall	227	210	94.1	17	5.6	18
Oct. 2	Mineola	158	109	69.0	49	31.0	57
Aug. 23	Overton	145	108	77.9	37	22.1	37
Aug. 23	Overton	230	181	78.7	49	21.3	54
Aug. 10	Palestine	460	266	57.8	194	42.2	194
Sept. 4	Palestine	118	104	88.1	14	11.9	15
Sept. 24	Roosevelt	46	12	26.1	34	73.9	74
Aug. 15	San Antonio	235	235	100.0	0	0.0	0
Aug. 16	Taylor	211	180	85.3	31	14.7	31
Sept. 19	Terrell	220	176	80.0	44	20.0	46
Aug. 9	Trinity	908	821	90.4	87	9.6	90
Aug. 9	Trinity	580	517	89.1	63	10.9	67
Aug. 30	Trinity	1,452	803	55.3	649	44.7	659
Aug. 30	Trinity	1,450	1,293	89.2	157	10.8	160
June 23	Victoria	10	10	100.0	0	0.0	0
June 28	Victoria	135	135	100.0	0	0.0	0
July 5	Victoria	885	843	95.3	42	4.7	42
July 18-20	Victoria	420	341	81.2	79	18.8	79
July 22	Victoria	533	442	83.0	91	17.0	91
Sept. 1	Victoria	472	404	85.6	68	14.4	71
July 25	Waco	691	639	92.5	52	7.5	52
Aug. 17	Waco	315	291	92.4	24	7.6	24
Aug. 28	Waco	932	829	89.0	103	11.0	103
Aug. 29	Waco	490	411	83.9	79	16.1	84
Aug. 29	Waco	260	233	89.6	27	10.4	28
Oct. 12	Waco	241	175	72.7	66	27.3	90
Total		20,315	16,683	82.1	3,632	17.9	4,018

TABLE XVI.—*Proportion of fruit destroyed by insect injury or by natural causes, Texas, 1906*—Continued.

D. FALLEN SQUARES.

Date.	Locality.	Total squares examined.	Squares without weevil stages.		Squares with weevil stages.		
			Number.	Per cent of total.	Number.	Per cent of total.	Number of weevil stages found.
July 12	Beeville	900	234	26.0	666	74.0	656
Aug. 8	Beeville	512	76	14.8	436	85.2	436
Aug. 13	Beeville	1,000	126	12.6	874	87.4	874
Sept. 3	Beeville	900	222	24.7	678	75.3	678
July 28	Brownsville	2,524	957	37.9	1,567	62.1	1,568
Aug. 3	Brownsville	130	17	13.8	113	86.2	115
Sept. 5	Brownsville	4,032	2,889	70.3	1,143	29.7	1,147
Sept. 29	Brownsville	456	199	43.6	257	56.4	265
Aug. 28	Calvert	353	40	11.3	313	88.7	315
Sept. 13	Calvert	1,033	341	33.0	692	67.0	722
July 10	Corpus Christi	718	283	39.4	435	60.6	438
Sept. 18	Corsicana	26	10	38.5	16	61.5	16
Aug. 31	Cuero	1,550	495	32.0	1,055	68.0	1,059
Aug. 29	Dallas	111	57	51.4	54	48.6	54
Aug. 17	Fullers	100	79	79.0	21	21.0	21
Sept. 3	Goliad	430	154	35.8	276	64.2	281
Sept. 3	Goliad	875	347	39.7	528	60.3	540
Aug. 30	Hallettsville	1,150	250	21.8	900	78.2	903
Aug. 30	Hallettsville	230	93	40.4	137	59.6	137
Sept. 24	Junction	383	254	66.3	129	33.7	129
Aug. 26	Kerrville	29	6	20.7	23	69.3	23
Sept. 3	Kerrville	17	5	29.4	12	70.6	12
Sept. 26	Lula	278	228	82.0	50	18.0	54
Aug. 23	Marshall	52	29	55.8	33	44.2	23
Aug. 10	Mineola	100	88	88.0	12	12.0	12
Aug. 10	Mineola	120	38	31.7	82	68.3	87
Oct. 2	Mineola	697	353	50.7	344	49.3	347
Aug. 23	Overton	148	35	23.7	113	76.3	113
Aug. 23	Overton	164	80	47.6	84	52.4	84
Aug. 10	Palestine	1,327	285	21.5	1,042	78.5	1,042
Sept. 4	Palestine	8	2	25.0	6	75.0	6
Sept. 24	Roosevelt	88	25	28.4	63	71.6	69
Aug. 15	San Antonio	83	53	63.9	30	36.1	33
Aug. 16	Taylor	79	35	45.6	44	54.4	44
Sept. 19	Terrell	88	35	40.0	53	60.0	53
Aug. 9	Trinity	900	347	38.6	553	61.7	553
Aug. 9	Trinity	887	393	44.3	494	55.7	494
Aug. 30	Trinity	614	225	36.6	389	63.4	390
Aug. 30	Trinity	240	124	50.2	116	49.8	116
June 16	Victoria	980	116	13.7	864	86.3	864
June 23–28	Victoria	3,496	518	14.8	2,978	85.2	2,978
July 5–9	Victoria	1,405	355	25.3	1,050	74.6	1,050
July 18–20	Victoria	679	197	29.0	482	71.0	494
July 22	Victoria	302	215	71.2	87	28.8	87
Sept. 1	Victoria	1,142	129	11.3	1,013	88.7	1,026
July 25	Waco	737	480	65.1	257	34.9	259
Aug. 17	Waco	170	131	77.0	39	23.0	39
Aug. 28	Waco	742	431	58.1	311	41.9	311
Aug. 29	Waco	1,300	711	54.7	589	45.3	591
Aug. 29	Waco	785	477	60.8	308	39.2	308
Oct. 12	Waco	1,284	1,032	80.4	252	19.6	253
Total		36,354	14,301	39.3	22,053	60.7	22,169

From Table XVI A, hanging, dried bolls, it appears that three-fourths of the number examined contained no weevil stage. In this case there were found 1.227 weevil stages for each boll which was found to contain any. The percentage containing some stage shows an exceedingly wide variation between the 1.3 per cent for San Antonio, where the infestation was slight, and the 83 per cent at Waco on September 20, where the infestation was very heavy. It seems that the presence or absence of a weevil stage has little, if anything, to do with the retention by the plant of a portion of its surplus fruit, but that the abundance of weevils in proportion to their food supply may be largely responsible for the variations which appear in the percentage of these dried, hanging bolls which contain some weevil stage.

In Table XVI B, among the hanging dried squares, nearly 59 per cent of these examined contained some weevil stage. In this case there were found an average of but 1.01 stages per square. The percentage containing weevil stages varies somewhat, as it did in the case of dried bolls, but the variations are not exactly parallel. One reason for this apparent lack of agreement may be found in the fact that weevils show considerable preference for squares, and therefore attack them to a much larger extent than they do the small bolls. Among the bolls an average of 24.6 per cent contained some stage of the weevil, while among the dried squares there were 58.8 per cent.

In Table XVI C, fallen bolls, it appears that an average of only about 18 per cent contained some weevil stage. In this case there were found 1.106 weevil stages for each boll found to contain any. Examinations in three localities failed to reveal any weevil stage in a total of 380 bolls. Two of these examinations were made at Victoria in June before weevils had become sufficiently abundant to attack bolls to any extent. The third case was at San Antonio, where, as is indicated by observations in the other classes of forms, the infestation was comparatively light. It is probable, however, that a more extensive examination would have revealed some weevil stages in fallen bolls at San Antonio.

In Table XVI D, fallen squares, it is shown that slightly over 60 per cent contained some weevil stage. In this very large series of examinations there were but 1.05 stages for each square containing any. As would naturally be expected, there is not quite so wide a range between the extremes in the percentage of total squares which were found to contain a weevil stage as in other classes of forms. The importance of fallen squares, as compared with other classes of infested fruit, is shown by the fact that, in the 36,354 fallen squares examined, were found 22,169 weevil stages; whereas, in the 40,166 forms in the other three classes for Texas, there were but 11,666 weevil stages. While 60.7 per cent of the fallen squares were found to contain some stage of the weevil, an average of the three other classes of forms showed stages in but 26 per cent. The special significance of these comparisons, from the standpoint of natural control of the weevil, may be appreciated when it is considered that the total mortality in fallen squares is much greater than in any other class of forms.

This may be more clearly understood if we consider a concrete illustration based upon the actual average percentages shown in Table III. In addition to the percentage of weevils found dead at the time of examination, it is reasonable to assume that had the stages been left in the undisturbed forms until all surviving weevils might have emerged, there would have been an increase in mortality fully equal to one-half of the percentage shown by the examinations. Based upon this mortality, a hypothetical illustration shows in a striking way the influence which the class of form may have upon the proportion of weevil stages reaching maturity therein.

TABLE XVII.—*Illustration of effect of natural control, as found, upon weevil development in each class of forms.*

Class of forms.	Number of weevil stages starting therein.	Number dying as by proportions found at examinations given herewith.	Additional number likely still to die before emergence.	Number of adult weevils emerging.
Dried, hanging bolls	100	30	15	55
Dried, hanging squares	100	53	27	20
Fallen bolls	100	33	17	50
Total for 3 classes above	300	116	59	125
Fallen squares	300	180	90	30

From this illustration it may be seen that the chances for a weevil to reach maturity are greatest in hanging bolls, second in fallen bolls, third in hanging squares, and least among fallen squares. Starting with three hundred stages, distributed equally among the first three classes of forms, between 40 and 45 per cent may be expected to become adult, while an equal number of stages in fallen squares may probably yield not more than 10 per cent of adults.

It is fortunate that under normal conditions a large majority of weevil stages develop in squares which fall to the ground. Because of this fact it is possible for the most important factors of natural control to exert their greatest influence in checking the multiplication of the weevils. Without the large degree of natural control, such as has been shown to have existed in 1906, the profitable production of cotton would, apparently, not be possible. Understanding something of the influence of these factors, as we now do, we can appreciate in some measure our indebtedness to them for making it possible to continue the culture of cotton throughout the area which still, in spite of the damage actually done by the weevil, produces more than one-third of the annual crop in the United States. We can appreciate also the importance of following such methods in the culture of cotton as are found to promote in the greatest degree the efficiency of any factor in the natural control of the weevil.

SUMMARY AND CONCLUSIONS.

If there be a fair amount of moisture in the soil up to the time squares begin to form, and there then ensues a period of from four to six weeks of hot dry weather, with mean average temperatures ranging from 75 to 85 degrees F., it may be expected that the weevils, though abundant theretofore, may be so effectively checked as to do little injury to the crop of that season.

An entire season of extreme drought, even without exceptionally high temperatures, will greatly reduce the number of weevils, but the crop will be small because of the continued lack of moisture. This condition may show little benefit from weevil control during that season, but will greatly favor the production of a large crop, if weather conditions be favorable, during the following season. The difference in effect of a drought during squaring season alone and during the entire season lies in the widely different effect which those conditions exert upon the number of weevils developed in the fall, upon the food supply available to the weevils until time for them to enter hibernation, and upon the shelter obtainable by the weevils during winter. In the former case many weevils may survive, in the latter few weevils will survive to attack the succeeding crop.

Winter conditions of unusual severity with frequent low temperatures and much rainfall have a beneficial effect by reducing the number of weevils surviving hibernation and by preventing the survival of old cotton roots.

By cultural practices it is possible to secure regularly as great reduction in weevil injury during the following season as occurs occasionally after winters of extreme severity.

Defoliation of cotton by the cotton leaf worms, if thorough and repeated, may be a very important factor in reducing the number of weevils in a field which may enter hibernation, or which are likely to survive. The planter can usually secure regularly much of the good effect of irregular leaf worm defoliations by destroying the cotton stalks early in the fall.

Fallen forms contain fully 70 per cent of the weevil stages developing in a field. These stages are exposed to the most effective action of heat and of ant attack. Only in case of the fallen forms is it possible to vary cultural practice so as to increase the effectiveness of these factors. The mortality occurring in fallen forms is fully four times as effective in controlling the weevil as is that in hanging forms.

Less than one-half of all the weevil stages were still alive when found. If these had been allowed to remain undisturbed, under the continued influence of the three factors of natural control studied, it is very probable that the total mortality resulting would finally have amounted to fully 70 per cent. From 10 to 15 per cent of mortality occurred from other causes than those given in the tables.

All factors of natural control seem to operate more effectively against weevil stages in squares than against those in bolls. Ants and heat or drying are the most important factors in each class. In bolls about two-thirds of the stages found were alive, while in squares but two-fifths were living.

The data used in this bulletin include examinations in twenty-eight localities, in several fields in each locality, and in seventeen places examinations upon from two to nine dates between June 15 and October 15, 1906. More than 86,000 forms were examined and 39,000 weevil stages were found.

Nearly all of the eleven localities having an average total mortality above the average for the twenty-eight localities examined are situated south of the center of cotton production in Texas.

Ants of the species *Solenopsis geminata* are more important in the summer control of the weevil than are heat and parasites combined.

The effectiveness of heat from sunshine is largely influenced by spacing of plants, which should be wide for best results, and by the coincident dryness of soil or atmosphere. The mortality from heat in two groups of localities having almost identical mean maximum temperatures varies as widely as between 7 and 27 per cent. Exact reasons for this great difference are not apparent. Average climatic variations do not appear to produce a corresponding variation in the average mortality of weevil stages.

Ants seem to enter only forms containing living stages of the weevil. Variations in mortality from ant attack may be due to varying abundance of the ants in different fields or localities. Their activity is evidently influenced by climatic conditions and may also be affected somewhat by cultural conditions.

All parasites attacking the weevil have other hosts. Parasite attack is much greater in hanging than it is in fallen forms. The abundance of parasites seems to depend largely upon the proximity of some other plant than cotton in which their usual hosts abound. Their attack upon the boll weevil is a promising adaptation to a new host and may increase in effectiveness.

Climatic and cultural conditions seem to have been less influential in producing the three highest percentages of mortality than were the ants alone.

The highest mortality from heat or drying was found at Corpus Christi, Tex., in coincidence with comparatively low average maximum and average mean temperatures, but after an exceptional drought extending over some eight or ten weeks. This occurred also in a well-tilled field where not more than one-half of the ground was shaded.

The proportion of clear to cloudy days and the relative rainfall seem to influence in considerable degree the effectiveness of high temperatures.

Comparison of mortality records in localities infested for not more than two years with those in localities infested for from three to ten years shows a total mortality averaging about 10 per cent greater in the section longer infested. This increase was due principally to the greater effectiveness of heat and parasites, while in the recently infested area ants were exceptionally effective. The principal reasons for these differences were probably the more moist climate and the more abundant ant distribution in the recently infested area.

Nearly 70 per cent of all mortality found from heat or drying occurred during the larval stage. The ratio of mortality percentages in each weevil stage from heat is: Adult 1, pupa 3, larva 9. An early shedding of infested forms is very desirable.

Whatever spacing may have been found advisable where weevils were not present, these records prove the general soundness of the recommendation for increasing the space allowed each plant where the weevils are abundant. Central Texas shows the high average mortality of 21.8 per cent by parasites in hanging squares, 8.4 per cent in hanging bolls, and 5.7 per cent in fallen squares. Owing to the small number of observations made in southwestern Texas, western Louisiana should really be ranked first, with 39.4 in average percentage of total mortality among hanging dried bolls, while central Texas is second, with 28.8 per cent. Among hanging dried squares central Texas stands first, with 65.4, and western Louisiana second, with 61.3 per cent. Among fallen bolls eastern Texas ranks first, with 50 per cent mortality, and western Louisiana second, with 33.4 per cent. In eastern Texas alone did the number of fallen bolls examined exceed the number of fallen squares. Among fallen squares southern Texas has a long lead in total mortality, with 70.7 per cent, as compared with central Texas, with 50 per cent. The high percentage found in this class is based upon much the largest series of examinations made for any class in any section, and the figures are therefore exceptionally reliable and significant.

In degree of benefit from natural control, the six groups of localities rank as follows in average percentage of total mortality

	Per cent.
Southern Texas	62.6
Central Texas	45.5
Western Louisiana	43.2
Eastern Texas	41.4
Northeastern Texas	31.9
Southwestern Texas	26.0

In examination of about 11,000 fallen forms collected between August 10 and August 31, 1905, 25 per cent were squares and 75 per cent were small bolls. The proportion between these forms varies greatly with the stage of growth in each field. In the examination of 62,593 fallen forms collected between June 15 and October 15, 1906, 64 per cent were squares and 36 per cent bolls. Among 24,363 hanging forms examined in 1906, 28.6 per cent were squares and 71.4 per cent bolls.

In a test of the effect of hand picking of infested fallen forms in 1905, it is probable that between 34,000 and 42,500 adult weevils were thereby prevented from emerging upon an area of 8 acres. In spite of this large destruction of weevils, the increased yield of seed cotton upon the test area averaged only about 50 pounds per acre as compared with a check area of similar size. This shows the tremendous importance and effectiveness of natural control, which frequently produces much greater increases in yield than 50 pounds of seed cotton per acre.

In the examination of 11,000 forms from Louisiana in 1906, only 44 per cent were found to contain a weevil stage. The balance of 56 per cent included many which had been injured by feeding of the weevils. Among the bolls 30 per cent and among squares 60 per cent contained some stage of a weevil. Probably few of the remainder of the squares had escaped some form of weevil attack, but a large proportion of the 70 per cent of bolls perished without any injury by the boll weevil.

In examinations of forms collected in Texas in 1906 among more than 14,000 dried, hanging bolls, hardly 25 per cent showed any stage of the weevil; among over 20,000 fallen bolls only 18 per cent had any stage; among 5,600 hanging dried squares nearly 60 per cent and among more than 36,000 fallen squares slightly over 60 per cent contained a weevil stage. Practically two-thirds of all weevil stages found in Texas were in the fallen squares.

The proportion among 100 weevil stages starting in each one of the four classes of forms which may be reasonably expected to reach maturity and emerge is as follows: Hanging dried bolls, 55; fallen bolls, 50; hanging dried squares, 20; fallen squares, 10.

Evidently we are indebted in a very large degree to the effectiveness of natural control for the possibility of continuing cotton production. Such cultural methods should be followed as shall exert the strongest influence upon hastening the maturity and increasing the yield of the crop. In addition to this, such cultural methods should be followed as will promote the highest efficiency of the factors in this natural control of the Mexican cotton boll weevil.

INDEX.

Alabama argillacea. (*See* Leaf-worm, cotton.) Page.

- Ants, factor in control of boll weevil 19, 24-25, 27-29, 30, 31, 33, 34, 37, 38, 40-41, 42, 43-44, 45-46, 47, 48, 49-50, 51-53, 54-59, 60, 61-62, 63, 74, 75
- Balance in nature 6
- Birds, factor in control of boll weevil 19, 22-23
- Bolls, fallen, boll weevil mortality 28-29, 30, 31-33, 51, 54-60, 61-62, 75
    - proportion destroyed by boll weevil versus natural causes 65-66, 69, 71, 72, 76
  - hanging dried, boll weevil mortality 27, 30, 31-33, 51, 54-60, 61, 75
    - proportion destroyed by boll weevil versus natural causes. 66, 67, 70-71, 72, 76
  - proportion among fallen cotton forms 64, 76
  - retention by plant of those dead 26
  - versus squares, mortality of boll weevil 33-35, 74
- Boll weevil, abundance and injuriousness as affected by humidity 11-12
  - area infested in United States 23
  - control by ants 19, 24-25, 27-29, 30, 31, 33, 34, 37, 38, 40-41, 42, 43-44, 45-46, 47, 48, 49-50, 51-53, 54-59, 60, 61-62, 63, 74, 75
    - birds 19, 22-23
    - climatic conditions 11-19, 37, 38-43, 74
    - collection of fallen forms 64-65, 76
    - cultural conditions 43-51, 74
    - destruction of cotton stalks in fall 18-19, 73
    - heat and drying 19, 23, 27-29, 30, 31, 32, 34-35, 36, 37, 38, 40-41, 42-43, 47-50, 51-53, 54-59, 60, 61, 62, 63, 74-75
    - leaf-worm (*Alabama argillacea*) 19, 20, 21-22, 73
    - parasites 19, 20-21, 23, 26, 27-29, 30, 31, 33, 34, 37, 38, 40-41, 42, 43-44. 49, 50, 51-53, 54-59, 60, 61, 62, 63, 74, 75
    - proliferation 19, 20, 33, 35
    - *Solenopsis geminata* 33
      (*See also* Ants.)
    - wide spacing of cotton plants 45-47, 75
    - winter conditions in Louisiana 16-17
  - developmental period, average length 35
  - dispersion in Louisiana 16
  - emergence signs in cotton square 24-25
  - in Louisiana, control by winter conditions 16-17
    - dispersion 16
  - mortality affected by rainfall 13-15, 17, 37, 38-39, 40-41, 42-43, 47-50, 75
    - temperature 11-19, 37, 40-43, 47-50, 73, 74, 75

Page.

Boll weevil, mortality in all classes of forms........ 30-31
- bolls versus squares........ 33-35, 74
- each class of forms for each section........ 60-62
- fallen bolls........ 28-29, 30, 31-33, 51, 54-60, 61-62, 75
  - forms........ 73-74
    - from ants........ 31, 33, 51
      - heat and drying........ 31, 32, 51
      - parasites........ 31, 33, 51
  - squares........ 29, 30, 31-32, 33, 44, 47, 51, 54-59, 60, 61-62, 75
- hanging dried bolls........ 27, 30, 31-33, 51, 54-60, 61-62, 75
  - squares........ 27-28, 30, 31-32, 33, 44, 51, 54-59, 60, 61, 75
  - forms........ 73-74
    - from ants........ 31, 33, 51
      - heat and drying........ 31, 32, 51
      - parasites........ 31, 33, 51
- Louisiana, western........ 54-55, 61, 62-63, 75
- squares versus bolls........ 33-35, 74
- Texas, central........ 57-58, 61, 62-63, 75
  - eastern........ 55, 61, 62-63, 75
  - northeastern........ 58-59, 62-63, 75
  - northern........ 61
  - southern........ 56-57, 61, 62-63, 75
  - southwestern........ 59, 61, 62-63, 75
- of adults in cotton forms........ 27-29, 37, 38, 40-41, 43, 54-59, 60, 62, 75
  - larvæ in cotton forms........ 27-29, 30, 37, 38, 40-41, 43, 54-59, 60, 62, 75
  - pupæ in cotton forms........ 27-29, 30, 37, 38, 40-41, 43, 54-59, 60, 62, 75
- natural control in various localities........ 35-38, 53-59, 61-63
- parasites more abundant in hanging than in fallen forms........ 30
- proportion of stages which may emerge from fallen bolls........ 76
  - squares........ 76
  - hanging dried bolls.. 76
    - squares 76

Climatic conditions in control of boll weevil........ 11-19, 37, 38-43, 74

Control, natural, of boll weevil, climatic factors involved........ 11-19, 37, 38-43, 74
- conclusions and summary........ 73-76
- conditions requiring consideration........ 11-12
- definition........ 6
- influence of dry season on succeeding season 14-15, 73
  - period [duration] of infestation. 51-53, 75
  - short drought in same season.. 12-14, 73
  - winter climatic conditions..... 15-19, 73
- in various classes of forms........ 26-31, 60-62, 75
  - localities........ 35-38, 53-59, 60-63, 75
- localities where greatest........ 74
- relationship of factors........ 19-23
- summary and conclusions........ 73-76

Cotton forms (*see also* Bolls and Squares).
- fallen, mortality of boll weevil........ 30, 31-33, 73-74

Page.
Cotton forms hanging, mortality of boll weevil.................... 30, 31–33, 73–74
proportion destroyed by natural causes versus boll weevil attack. 64–72
retention by plant of those dead.................... 25–26
versus shedding for control of boll weevil.................... 31–33
leaf-worm. (*See* Leaf-worm, cotton.)
retention by plant of dead squares and bolls.................... 25–26
stalks, fall destruction for control of boll weevil.................... 18–19, 73
wide spacing for control of boll weevil.................... 45–47, 75
Cultural conditions in control of boll weevil.................... 43–51, 74
practices, value in control of boll weevil.................... 18–19, 73, 76
Ectatomma tuberculatum, failure to maintain itself in Texas.................... 23
Gelatinization. (*See* Proliferation.)
Heat and drying, factor in control of boll weevil.................... 19, 23, 27–29, 30, 31, 32, 34–35, 36, 37, 38, 40–41, 42–43, 47–50, 51–53, 54–59, 60, 61, 62, 63, 74–75
Humidity (*see also* Rainfall).
as affecting abundance and injuriousness of boll weevil.................... 11–12
relative.................... 39
Icterus hypomelas, enemy of boll weevil.................... 22
"Kelep." (See *Ectatomma tuberculatum.*)
Leaf-worm, cotton, factor in control of boll weevil.................... 19, 20, 21–22, 73
Louisiana, boll weevil control by winter conditions.................... 16–17
dispersion.................... 16
western, boll weevil mortality.................... 54–55, 61, 62–63, 75
Parasites, factor in control of boll weevil.................... 19, 20–21, 23, 26, 27–29, 30, 31, 33, 34, 37, 38, 40–41, 42, 43–44, 49, 50, 51–53, 54–59, 60, 61, 62, 63, 74, 75
of boll weevil more abundant in hanging than in fallen forms.................... 30
Proliferation, factor in control of boll weevil.................... 19, 20, 33, 35
Rainfall (*see also* Humidity).
as affecting mortality of boll weevil.................... 13–15, 17, 37, 38–39, 40–41, 42–43, 47–50, 75
Solenopsis geminata (*see also* Ants).
enemy of boll weevil.................... 24–25, 33
Squares, fallen, boll weevil mortality.................... 29, 30, 31–32, 33, 44, 47, 51, 54–59, 61–62, 75
proportion destroyed by boll weevil versus natural causes.................... 65, 70, 71, 72, 76
hanging dried, boll weevil mortality.................... 27–28, 30, 31–32, 33, 44, 51, 54–59, 60, 61, 75
proportion destroyed by boll weevil versus natural causes.................... 66, 68, 71, 72, 76
proportion among fallen cotton forms.................... 64, 76
retention by plant of those dead.................... 25–26
versus bolls, mortality of boll weevil.................... 33–35, 74
Statistical data, value in study of natural control of boll weevil.................... 25
Temperature (*see also* Heat and drying).
as affecting mortality of boll weevil.................... 11–19, 37, 40–43, 47–50, 73, 74, 75
Texas, central, boll weevil mortality.................... 57–58, 61, 62–63, 75
eastern, boll weevil mortality.................... 55, 61, 62–63, 75
northeastern, boll weevil mortality.................... 58–59, 62–63, 75
northern, boll weevil mortality.................... 61
southern, boll weevil mortality.................... 56–57, 61, 62–63, 75
southwestern, boll weevil mortality.................... 59, 61, 62–63, 75

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 73.
L. O. HOWARD, Entomologist and Chief of Bureau.

STUDIES OF PARASITES OF THE COTTON BOLL WEEVIL.

BY

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ISSUED JANUARY 21, 1908.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1908.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., July 29, 1907.

Sir: I have the honor to transmit herewith a manuscript entitled "Studies of Parasites of the Cotton Boll Weevil," by Mr. W. Dwight Pierce, a special field agent of this Bureau engaged in cotton boll weevil investigations. Some of the preliminary results of these studies were published as Bulletin No. 63, Part II, of the Bureau of Entomology, under the title "Notes on the Biology of Certain Weevils Related to the Cotton Boll Weevil." The boll weevil in the United States is now known to be attacked by several species of parasitic insects. These have not been introduced with the boll weevil from the country from which the latter spread, but they have been here for years as parasites of other species of weevils occurring in the territory now infested by the boll weevil. The present manuscript contains a record of investigations of these parasites and deals especially with the possible practical applications which may be made of the results gained. I recommend its publication as Bulletin No. 73 of this Bureau.

Respectfully,
L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The boll weevil has been present in the United States for fourteen years. At this time it is doing serious damage to cotton in four States, and during the present season undoubtedly will invade a fifth. In regions like Central America, where the insect has existed for many years, there are various influences that serve to hold it in check. In this country similar influences are beginning to be in evidence. Among the direct factors in the natural control of the boll weevil that are now at work are the following: Heat and dryness, the native ant *Solenopsis geminata*,[a] winter temperatures, proliferation, parasites, defoliation by the cotton leaf-worm, determinate growth, and birds. Of these, proliferation and birds have already received careful special attention, while the work of the native ant has received preliminary notice. The other factors have also been more or less discussed in the publications of the Bureau of Entomology and elsewhere, and more extensive studies of certain ones will be discussed by Dr. W. E. Hinds in Bulletin No. 74 of this Bureau.

While the work of parasites, discussed in this bulletin, is not at present one of the most important factors in the control of the boll weevil, the indications are clear that its importance will grow rapidly. Moreover, the matter has special interest for the reason that it is not unlikely that practical means may be devised to increase the work of the parasites.

In the United States fifteen species of insects which seek the weevil in its immature stages are known. These insects have not been introduced artificially from other countries, nor have they followed the boll weevil into this country. They have all been present for years, and have been actively parasitic upon other species of weevils found within the boll-weevil-infested territory. In fact, there are a great many closely related weevils of the genus Anthonomus, some of which are very common in parts of the cotton belt. These weevils are frequently held completely in control by parasites, and for the most part the parasites are not confined to the attack of a single species of weevil. In many cases the boll weevil may appear in a

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[a] Not to be confused with the kelep, the introduction of which has proved unsuccessful.

region in which the parasites have reached the critical point of maximum parasitism, and in such cases the overflow of parasites must attack some other host, which naturally will be the predominant insect of the same group as their former host. It is therefore not at all surprising that when the boll weevil appears by millions in a new region these same parasites in the very first generation of the boll weevil become adapted to it as a new host.

The distribution of the other species of weevils is limited to floral or geographical regions, and consequently, to a less extent, the parasites are also limited. This condition is illustrated by the distribution of the species of parasites which have already attacked the boll weevil. It is safe to say that as the pest advances to the East and North still other insects will adopt it as their host in the same measure as it invades regions inhabited by other species of weevils. In many transitional regions there is a strong possibility that several species of weevils may be very highly parasitized and that all of them will lend parasites to the attack of the boll weevil. In such regions especially there are to be expected instances of very high percentages of parasitism. At Waco, Tex., where two regions border upon each other, a parasitism of over 40 per cent occurred at one time during the season of 1906.

There are two possible practical applications of the information obtained and recorded in this bulletin, both, however, requiring expert entomological knowledge and experience. These are: (1) The propagation and collection of parasites, and their distribution in regions where the same species are either present in but small numbers or altogether absent, and (2) the elimination of related weevils by the destruction of their food plants in or about cotton fields, thereby forcing the parasites to transfer their attention to the boll weevil.

Under the plan of artificial propagation by picking large numbers of squares in fields where the weevil is highly parasitized and placing them in cages adapted for such breeding, a large number of parasites might be obtained. The weevils should then be killed. These parasites could be released in fields with a low percentage of parasitism, and the results under favorable conditions should be apparent after one generation of the boll weevil. In this bulletin will be found an account of an apparently very successful experiment of this kind, in which, at Dallas, Tex., the percentage of parasitism was brought up 9.1 per cent by the introductions of parasites from Waco, about 100 miles away.

Under the plan of eliminating, more or less, the natural hosts of parasites that will attack the boll weevil (by the destruction of their food plants) no experiments have yet been performed. As an example of the possibilities, however, it may be mentioned that there is a common but easily controlled weed (*Croton* spp.) grown in and about cotton fields throughout the South the seed pods of which are infested by a weevil (*Anthonomus albopilosus*) closely allied to the boll weevil. This weevil has three different parasites, which also attack the boll weevil. The croton weevil does not feed upon cotton or any other cultivated plants. By merely mowing down or otherwise removing the croton plants at the proper time there could be no danger from the croton weevil, while its parasites would be forced to turn their attention to the boll weevil. It is conceivable that the encouragement of the croton plants or the actual planting and later removal might be undertaken in order to obtain the best possible results.

Other results of practical application are recorded in this bulletin. Among them may be mentioned the fact that fallen forms exposed to the sun show higher parasitism than those shaded, due undoubtedly to the light-loving character of the parasites. This gives another reason for the wide spacing of the plants and the use of varieties of cotton with the minimum tendency to form leafage and the greatest tendency to shed their leaves in the fall.

W. D. HUNTER,
In Charge of Cotton Boll Weevil Investigations.

CONTENTS.

	Page.
Introduction	9
History	10
The work on parasites in 1906	11
I. Examination work	11
Records prior to 1906	12
Breeding records of 1906	13
Most favorable plant conditions for parasitism of the boll weevil	15
Field conditions	17
Geographical considerations	18
Boll weevil status	19
Boll weevil chronology	21
Conclusions	21
II. Propagation work	22
1. Interior work—transfer or artificial propagation of parasites	22
2. Field work—release of parasites	24
III. Parasite breeding work	27
Occurrence of species	28
Geographical and seasonal distribution of parasites	31
Biological notes on the parasites	32
IV. The sources of the parasites	41
Parasites known to attack Rhynchophora	41
Biologies of the weevils contributing parasites	44
Rotation of hosts	48
V. Conclusions and prospects	50
Bibliography	50
Index	53

ILLUSTRATIONS.

PLATES.

Page.

PLATE I. Parasites of weevils. Fig. 1.—*Eurytoma tylodermatis*, pupa. Fig. 2.—*Catolaccus incertus*, pupa. Fig. 3.—*Cerambycobius cyaniceps*, pupa. Fig. 4.—*Microdontomerus anthonomi*, pupa. Fig. 5.—Larva of Bracon. Fig. 6.—*Bracon mellitor*, pupa. Fig. 7.—Larva of chalcidoid 34

II. The purple mallow (*Callirrhoe involucrata*), a food plant of two weevils related to the boll weevil. Fig. *A*.—The buds and flowers, which are subject to attack by *Anthonomus fulvus*, and the capsule, subject to attack of *Macrorhoptus estriatus*. Fig. *B*.—Bud infested by *Anthonomus fulvus*. Fig. *C*.—Flower injured by adult weevil of *Anthonomus fulvus* 46

III. Biologies of weevils. Fig. *A*.—Pepper, showing egg punctures of *Anthonomus eugenii*. Fig. *B*.—Head of *Sideranthus rubiginosus*, showing cell of *Desmoris scapalis*. Fig. *C*.—Pepper, showing larva of *Anthonomus eugenii* in situ. Fig. *D*.—Head of *Sideranthus rubiginosus*, with larva of *Desmoris scapalis* in its cell. Fig. *E*.—Section of cotton square, showing pupa of *Anthonomus grandis* and pupa of primary parasite *Catolaccus incertus*. Fig. *F*.—Earthen cell of larva of *Desmoris scapalis*. Fig. *G*.—*Desmoris scapalis*, adult weevil 46

TEXT FIGURES.

FIG. 1. *Bracon mellitor*, parasite of boll weevil 10

2. *Pediculoides ventricosus*, mite enemy of boll weevil 10

3. *Sigalphus curculionis* 11

4. Map of Texas, divided into geographical regions and illustrating average percentage of parasitism of the boll weevil in all cotton forms 19

5. Diagram of cotton plantation of H. O. Samuel, Dallas, Tex., of 64.4 acres, showing location of plats where observations and experiments on boll-weevil parasitism were made 25

6. Occurrence of *Catolaccus incertus*, *Bracon mellitor*, *Cerambycobius cyaniceps*, and *Eurytoma tylodermatis* in Texas and western Louisiana. 30

STUDIES OF PARASITES OF THE COTTON BOLL WEEVIL.

INTRODUCTION.

Although the boll weevil (*Anthonomus grandis* Boh.) has shown adaptation to many diverse conditions, it is not free from parasites. From the work detailed in this bulletin it has become apparent that certain enemies attack it in arid regions and certain others in humid regions; that some species attack principally larvæ in dried or sun-exposed forms, while other species attack the weevil stages in moist, decaying forms; that some species work most readily in prairie country, while others prefer woodland. The weevil does not escape parasitism by dispersion, for the local parasites are capable of adaptation and attack the boll weevil in its first generation.

Being a species with an all-season food plant, *Anthonomus grandis* has made a decisive gain over most of its near relatives, which are confined to more or less limited periods because of the shorter seasons of their host plants. The most active weevil parasites in the South have become adjusted to one host after another until in most localities they have a regular seasonal rotation of hosts. From this multiplicity of parasitic relations it is but natural to evolve a new tendency and to attack the most abundant species of the locality, namely, the boll weevil.

As the native weevil hosts are more or less limited in distribution, it is found that the boll-weevil parasites are likewise geographically restricted. The combined activity of two or more species in certain favored districts has been the cause of forming three known centers of intensive parasitism in Texas, of which the most important is near Waco; the next around Goliad, Cuero, and Victoria, and the third in eastern Texas. The agencies forming these centers are in no case identical. *Catolaccus incertus* is the most active parasite at Brownsville, Tex., and Orange, La. *Bracon mellitor* (fig. 1), which is the predominant parasite for the entire infested area, is the most active in the entire western half of Texas. *Cerambycobius cyaniceps* is predominant in northeastern Texas. *Eurytoma tylodermatis* shows its greatest activity at Overton and Dallas.

HISTORY.

Prior to the year 1906 very little information concerning the parasites of the boll weevil had been accumulated. In 1895 Townsend mentioned a small hymenopterous parasite; also recorded the suspicious occurrence of several species of Scymnus in the squares, and mentioned that a fungoid parasite, a species of Cordyceps, "was found growing out of a dead pupa in its cell in a boll, November 26, in a field in San Juan Allende, Mexico." (Townsend, 1895.)[a] In 1896 Doctor Howard stated that the parasites were only abundant late in the fall and that from "15 to 20 per cent of the weevil larvæ in fallen squares in November at Beeville and Kenedy were destroyed by parasites." (Howard, 1897.)

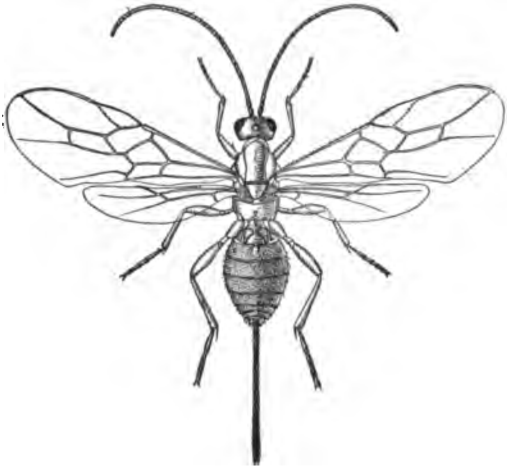

FIG. 1.—*Bracon mellitor*, parasite of boll weevil. Much enlarged (from Hunter and Hinds).

In 1901 Professor Herrera published a preliminary note concerning *Pediculoides ventricosus* Newp. (fig. 2) (Rangel, 1901b, p. 206), and in the same year a more extensive note on the work of this mite was published by Rangel. In testing the mite's ability to propagate, 250 squares were divided into lots of 50 each and an infested larva placed with each lot for four days. One hundred check squares were used. At the time of examination the check squares were free from the mites, while the others contained 193 weevil stages, of which 61 were attacked by Pediculoides; in other words, 31.6 per cent were parasit-

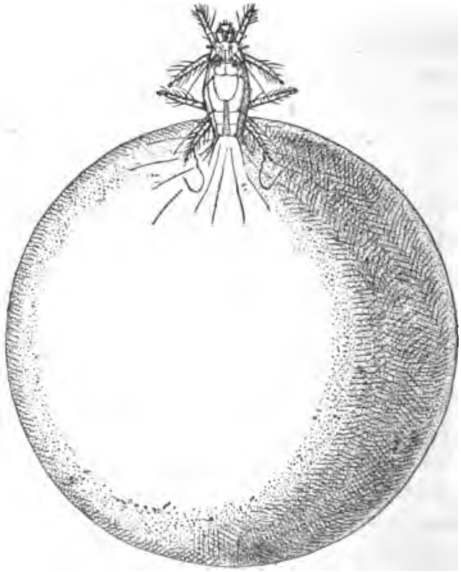

FIG. 2.—*Pediculoides ventricosus*, mite enemy of boll weevil. Much enlarged (adapted from Brucker).

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[a] Bibliography, pp. 50–51.

ized. A small field test proved that the mites increased and spread (Rangel, 1901c).

In 1902 Dr. Wm. H. Ashmead described *Bruchophagus herreræ*, from Coahuila, Mexico, as a primary parasite of the boll weevil (Ashmead, 1902). In the same year Prof. F. W. Mally recorded the fact that *Bracon mellitor* Say and *Cerambycobius* (*Eupelmus*) *cyaniceps* Ashm. had, since 1899, been bred by him in considerable numbers from the weevil. He also recorded a species of Eurytoma (Mally, 1902). In 1904 Hunter and Hinds recorded additional primary parasites as follows: *Sigalphus curculionis* Fitch (fig. 3), *Catolaccus incertus* Ashm., *Urosigalphus* (*robustus* Ashm.), *Bracon* (*dorsator* Say), and *Eurytoma tylodermatis* Ashm., as well as an entomogenous fungus, *Aspergillus* sp. (Hunter and Hinds, 1904, pp. 104–110). The determination of this Urosigalphus has been found incorrect. It has just been described as *Urosigalphus anthonomi* Cwfd. (Crawford, 1907a). The form known under the name of *Bracon dorsator* is merely a small, melanistic, fall form of *Bracon mellitor* Say. Finally, Banks has described a mite, *Tyroglyphus breviceps*, collected at Victoria, Tex., from boll weevil larvæ (Banks, 1906, p. 17).

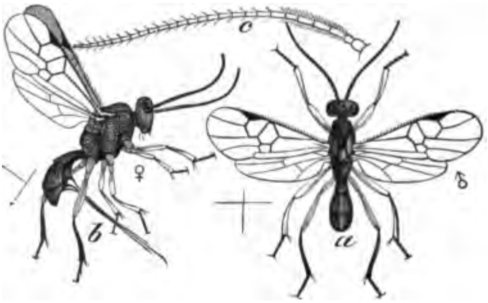

FIG. 3.—*Sigalphus curculionis*: *a*, male; *b*, female; *c*, antenna. All enlarged (after Riley).

THE WORK ON PARASITES IN 1906.

As the work of the year naturally divided itself into distinct sections, it may be thus divided for treatment in this report:

I. Examination work—ascertaining the general status of boll weevil parasitism.
II. Propagation work—attempting to increase the percentage of parasitism by release of parasites.
III. Breeding work—study of the biology of the parasites.
IV. Source work—study of the surrounding field conditions in order to ascertain the hosts which have contributed the parasites, and to learn the biology of each of these hosts.
V. Conclusions—a review of the situation as a whole.

I. EXAMINATION WORK.

In order to arrive at a proper knowledge of the status of boll weevil parasitism large collections of infested squares and bolls under various plant and field conditions were made in many parts of the weevil territory. This material was immediately shipped to the laboratory and examined by the various members of the laboratory force. Messrs. Hinds, Bishopp, Crawford, Cushman, Jones, Morgan, Pratt, and Yothers were engaged at various times in the collection of infested material and the more important work of examination. Upon their accuracy of observation the finding of the parasites was dependent, and to them belongs credit for the amount of figures herewith presented relating to the percentage of parasitism. A careful tabulated record was kept of all stages of the weevil, alive or dead, and all parasites were isolated in tubes. Each collecting lot received a number and each individual a subnumber, and its stage and the nature of its parasitism were recorded. As each parasite matured the record was placed opposite its number, and the insect was either used in experiments or laid aside for the collection. In this manner there could seldom be an error as to the nature of the parasitism, as all evidence was in the tube.

RECORDS PRIOR TO 1906.

In previous years no regular method of making the parasite records was in use, and consequently there is difficulty in the comparison of the former conditions with those now prevalent. In some cases the percentage was obtained from the breeding records only, and at other times by an examination for the total number of stages present.

In 1902 three observations were made between July 31 and August 11 at Calvert, Guadalupe, and Victoria. The figures obtained included only bred stages, omitting consideration of stages killed by heat, fungi, ants, crushing, etc.

In 1903 Dr. A. W. Morrill first pointed out in his notes that parasites occur in dry hanging forms,[a] and also in bolls. No other mention of the former condition can be found prior to 1906. Only two observations were made, both being at Victoria, in June.

In 1905 four examinations of bolls were made during March, at Calvert, Palestine, Runge, and Victoria, in order to ascertain the condition of hibernating stages. These examinations consider the total number of stages found hibernating in the bolls. The figures are important, as they prove that the parasites also hibernate in bolls.

During August of the same year nine examinations were made at Gurley, Quinlan, Victoria, and Waco. These figures were obtained from fallen forms and included the total number of stages in the forms.

In 1902 and 1903 the figures obtained must give a higher percentage of parasitism than actually occurred, as no account was taken of the stages dead from other causes. It is also very unsatisfactory to take the entire percentage of parasitism in all forms on account of the differences which prevail between squares and bolls and between fallen and hanging squares or bolls. However, taking the figures as they are, we have the following results:

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[a] The term "forms" has been used to designate a mixture of squares and bolls.

TABLE I.—*Total percentage of parasitism of the boll weevil, by years, prior to 1906.*

Year.	Months.	Weevil stages.	Parasites.	Percentage of parasitism.
1902	July 31 to August 11	601	6	0.99
1903	June 3 to 9	178	6	3.37
1905	March 1 to 23 (hibernating)	1,005	32	3.18
1905	August 12 to 31	1,702	21	1.23

In 1905 some of the records differentiated between squares and bolls, so that a comparison may be given between the percentages of parasitism in each.

TABLE II.—*Percentage of parasitism of the boll weevil in fallen forms at Gurley, Quinlan, Victoria, and Waco, Tex., in 1905.*

Form.	Weevil stages.	Parasites.	Percentage of parasitism.
Squares	852	17	1.99
Bolls	123	1	.81

BREEDING RECORDS OF 1906.

Although the work of 1906 was very incomplete in some respects, it is representative of the conditions. The facts have been ascertained one at a time, and as each one has been proved, it has been found that more complete records should have been taken earlier in the season. The material was collected at 25 representative localities in Texas, 2 in Indian Territory, and 5 in Louisiana. Seventy collections of infested forms were made, comprising about 87,000 bolls and squares. The result is that these infested forms contained 39,183 weevil stages, of which 1,689, or 4.31 per cent, were parasitized. The material collected was separated into lots, according to location and the nature of the forms.

A brief classification of the results, by months and by the four plant conditions, gives some very important information. In the first place, the percentage of parasitism is, to all intents and purposes, about equal throughout the season and not highest in the fall. It must, of course, be borne in mind that the collections were not made at regular intervals at stated places, but are from different localities each month and include different factors. During September and October a number of localities on the extreme border line were examined, but the percentage is not appreciably altered. The plant conditions were altered also, so that one month there might be more squares than bolls, and another month more bolls than squares, examined. A correct view of the monthly variation may be obtained by an examination of the complete tables of observations, which are given on succeeding pages. It will be noticed in that connection that there is no graduated seasonal wave of parasitism. Other and still unknown factors enter into the problem.

The following summary also discloses the fact that hanging forms provide conditions superior to those afforded by fallen forms, and that squares are more favorable than bolls.

Finally, it appears by comparison with the table of results for previous years that there has been a gain in the total percentage of parasitism as well as in the two classes of forms.

Table III.—*Percentage of parasitism of the boll weevil, by months, in 1906.*

Month.	Fallen squares.			Hanging squares.			Fallen bolls.			Hanging bolls.			Total.		
	Stages.	Parasites.	Per cent.	Stages.	Parasites.	Per cent.	Stages.	Parasites.	Per cent.	Stages.	Parasites.	Per cent.	Stages.	Parasites.	Per cent.
1906.															
June	3,831	118	3.08	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	3,831	118	3.08
July	4,621	210	4.54	247	76	30.76	169	0	0.00	22	0	0.00	5,059	286	5.65
August	10,342	174	1.68	2,973	348	11.70	2,490	20	.80	2,925	192	6.54	18,730	734	3.91
September	5,665	286	5.04	1,883	117	6.26	1,591	23	1.44	1,140	67	5.87	10,279	493	4.79
October	347	8	2.30	20	0	0.00	57	1	1.75	860	49	5.69	1,284	58	4.51
Entire season	24,806	796	3.20	5,123	541	10.56	4,307	44	1.02	4,947	308	6.22	39,183	1,689	4.31

[a] No records made.

The observations for June were made only at Victoria; those for October were made at Dallas for hanging forms and at Mineola for fallen forms.

Owing to the extensiveness of the tables the figures are considerably condensed, but still retain the value of their records. Numerous cases of high parasitism were found, of which the following may be cited as notable examples:

	Number of stages.	Per cent parasitized.
Fallen squares:		
Roosevelt, Tex.,[a] September 24	69	14.4
Brownsville, Tex.,[a] September 5	1,147	12.4
Hanging squares:		
Waco, Tex., July 25	99	52.6
Waco, Tex., September 20	109	23.8
Cuero, Tex., August 31	347	21.3
Fallen bolls:		
Corsicana, Tex., September 18	34	5.9
Junction, Tex., September 24	17	5.8
Hanging bolls:		
Marshall, Tex., August 22	52	13.5
Trinity, Tex., August 9	142	12.0
Waco, Tex., September 20	303	11.8

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[a] In both of these localities fallen squares would naturally be dry.

Numerous other high percentages were found, but these will convey an impression as to the promises of success obtained.

In the table herewith presented only the totals for each locality are given, and in more specific tables the seasonal variation at given localities will be recorded separately.

MOST FAVORABLE PLANT CONDITIONS FOR PARASITISM OF THE BOLL WEEVIL.

TABLE IV.—*Most favorable plant conditions for parasitism of the boll weevil.*

Locality.	Season.	Squares fallen.			Squares hanging.			Bolls fallen.			Bolls hanging.			Totals.		
		Stages.	Parasites.	Per cent of parasitism.	Stages.	Parasites.	Per cent of parasitism.	Stages.	Parasites.	Per cent of parasitism.	Stages.	Parasites.	Per cent of parasitism.	Stages.	Parasites.	Per cent of parasitism.
TEXAS.	1906.															
Brownsville	July 28–September 29.	3,095	202	6.5	....	....	....	384	13	3.3	....	....	....	3,479	215	6.1
Beeville	July 12–September 3.	2,660	36	1.3	....	....	....	324	0	0.0	....	....	....	2,984	36	1.2
Corpus Christi	July 10	438	39	9.0	....	....	....	20	0	0.0	....	....	....	458	39	8.5
Goliad	August 7 – September 3.	821	70	8.5	209	29	13.8	133	3	2.2	265	13	4.9	1,428	115	8.0
San Antonio	August 15	33	0	0.0	....	....	....	....	....	....	....	....	....	33	0	0.0
Kerrville	August 26–September 3.	38	4	10.5	....	....	....	295	7	2.3	....	....	....	333	11	3.3
Roosevelt	September 24	69	10	14.4	....	....	....	74	0	0.0	....	....	....	143	10	6.9
Junction	do	129	11	8.2	....	....	....	17	1	5.8	....	....	....	146	12	8.2
Mountain Home.	September 13	93	0	0.0	....	....	....	....	....	....	....	....	....	93	0	0.0
Lula	September 26	95	0	0.0	....	....	....	....	....	....	....	....	....	95	0	0.0
16 miles south of Roosevelt.	September 25	81	2	2.4	....	....	....	9	0	0.0	....	....	....	90	2	2.2
Cuero	August 9–31	1,059	11	1.0	439	87	19.9	80	0	0.0	189	2	1.0	1,767	100	5.5
Hallettsville	August 9–30	1,040	5	0.4	401	37	9.2	93	1	1.0	295	11	3.7	1,829	54	2.8
Victoria	June 16–September 1.	6,557	203	3.0	802	82	10.2	162	0	0.0	201	1	0.5	7,722	286	3.7
Taylor	August 16	153	1	0.6	160	8	5.0	63	1	1.5	40	1	2.5	416	11	2.6
Waco	July 25–September 20.	1,508	128	8.4	460	126	27.3	283	5	1.7	746	83	11.1	2,997	342	11.4
Calvert	August 22–September 13.	1,054	15	1.4	81	8	9.8	347	0	0.0	181	12	6.6	1,663	35	2.1
Corsicana	August 23–September 18.	16	0	0.0	102	12	11.7	34	2	5.9	176	6	3.4	328	20	6.0
Palestine	August 10–September 4.	1,054	14	1.3	414	48	11.5	209	1	0.4	211	7	3.3	1,888	70	3.7
Trinity	August 9–30	1,554	20	1.2	169	21	12.4	949	4	0.4	269	28	10.3	2,941	73	2.4
Dallas	August 17–October 6.	75	0	0.0	150	7	4.6	74	0	0.0	1,068	64	5.9	1,367	71	5.1
Terrell	September 19	53	0	0.0	....	....	....	46	0	0.0	....	....	....	99	0	0.0
Mineola	August 10–October 2.	445	9	2.0	....	....	....	57	1	1.8	....	....	....	502	10	2.0
Overton	August 23	197	2	1.0	45	1	2.2	37	0	0.0	89	4	4.5	368	7	1.9
Marshall	August 22	23	0	0.0	6	1	16.6	18	0	0.0	52	7	13.5	99	8	8.0
INDIAN TERRITORY.																
Fort Towson	September 12	....	....	....	521	0	0.0	....	....	....	....	....	....	521	0	0.0
Kosoma	September 14	....	....	....	64	0	0.0	....	....	....	....	....	....	64	0	0.0
LOUISIANA.																
Mansfield	August 24–September 29.	491	3	0.6	249	7	2.9	211	0	0.0	626	37	5.9	1,577	47	2.9
Many	August 23	1,315	6	0.4	633	66	10.4	321	5	1.5	539	32	5.9	2,808	109	3.8
Orange	September 23–30	435	5	1.1	....	....	....	67	0	0.0	....	....	....	502	5	0.9
Minden	September 8	....	....	....	218	1	0.5	....	....	....	....	....	....	218	1	0.5
Johnsons Bayou.	August 22	225	0	0.0	....	....	....	....	....	....	....	....	....	225	0	0.0
Total	....	24,806	796	3.2	5,123	541	10.5	4,307	44	1.02	4,947	308	6.2	39,183	1,689	4.3

The records from only five points extend into three months, and these may be taken as indicative of the seasonal variation at a given locality.

TABLE V.—*Parasitism of the boll weevil in fallen squares, Brownsville, Tex.*

Date.	Stages.	Parasites.	Percentage parasitized.
1906.			
July 28	1,568	50	3.2
August 3	115	2	1.7
September 5	1,147	142	12.4
September 29	265	8	3.0

TABLE VI.—*Parasitism of the boll weevil in fallen squares, Beeville, Tex.*

Date.	Stages.	Parasites.	Percentage parasitized.
1906.			
July 12	656	26	4.0
August 8	442	2	.45
August 13	884	2	.22
September 3	678	6	.9

TABLE VII.—*Parasitism of the boll weevil in fallen squares, Victoria, Tex.*

Date.	Stages.	Parasites.	Percentage parasitized.
1906.			
June 16	864	15	1.8
June 23	667	9	1.3
June 25	396	11	3.0
June 26	652	26	3.9
June 27	829	33	4.0
June 28	423	24	5.7
July 5	535	19	3.5
July 9	560	13	2.3
July 20	518	32	6.1
July 22	87	5	5.7
September 1	1,026	16	1.6

TABLE VIII.—*Parasitism of the boll weevil in all forms, Waco, Tex.*

Date.	Fallen squares.			Hanging squares.			Fallen bolls.			Hanging bolls.		
	Stages.	Parasites.	Per cent of parasitism.	Stages.	Parasites.	Per cent of parasitism.	Stages.	Parasites.	Per cent of parasitism.	Stages.	Parasites.	Per cent of parasitism.
1906.												
July 25	259	26	10.0	99	52	52.6	44	0	0.0	22	0	0.0
August 17	32	2	6.2	22	3	13.6	24	0	0.0	16	0	0.0
August 28	1,217	100	8.2	230	45	19.5	215	5	2.3	405	47	11.6
September 20	......	......	......	109	26	23.8	......	......	......	303	36	11.8

TABLE IX.—*Parasitism of the boll weevil in hanging forms, Dallas, Tex.*

Date.	Hanging squares.			Hanging bolls.		
	Stages.	Parasites.	Per cent of parasitism.	Stages.	Parasites.	Per cent of parasitism.
1906.						
August 29	12	1	8.5	26	0	0.0
September 12	118	6	5.0	182	15	8.2
October 2	8	0	0.0	250	10	4.0
October 6	12	0	0.0	610	39	6.3

The only one of these tables in which there appears any definite progression is the Victoria table, in which there is a regular increase of percentage throughout the last half of June.

FIELD CONDITIONS.

In order to arrive at an explanation for the obviously irregular conditions of parasitism, the figures have also been rearranged according to field conditions. It was found that generally hanging forms in wooded or cleared country were more highly parasitized than those on prairie land. The only definite comparisons which could be found were as follows:

TABLE X.—*Percentage of parasitism of the boll weevil in forms in woodland and on prairie.*

Locality.	Date.	Woodland.		Prairie.	
		Hanging forms.	Fallen forms.	Hanging forms.	Fallen forms.
	1906.				
Goliad	September 3	11.2	8.2	6.0	6.4
Waco	September 19	14.9		14.6	

Stages in fallen forms on prairie land were found to have a higher general percentage of parasitism than those in woodland, although the definite case of Goliad gives a different condition. It is only necessary to quote the highest percentages reached in each condition to give support to these statements.

The highest percentage in hanging forms on woodland was 42.6.

The highest percentage in fallen forms on woodland was 8.3.

The highest percentage in hanging forms on prairie was 14.6.

The highest percentage in fallen forms on prairie was 10.1.

Considerable contradictory matter was brought out in comparing the parasitism in fallen forms in shade and in those exposed to the sun. The weight of evidence supports the statement that those fallen and exposed to sunlight are more highly parasitized than those which fall on moist shaded soil. Only five definite comparisons can be presented to show the irregularities which exist.

TABLE XI.—*Parasitism of the boll weevil in fallen forms in sun and shade.*

Locality.	Date.	Woodland.		Prairie.	
		Shade.	Sun.	Shade.	Sun.
	1906.				
Mansfield, La	August 24	0.54	1.09		
Taylor, Tex	August 16			0.69	1.3
Trinity, Tex	August 8	2.3	1.07		
Victoria, Tex	July 20				6.5
Victoria, Tex	July 22			2.6	
Waco, Tex	August 29	8.7	6.8		

The highest percentages obtained in each class are as follows:

In shade on woodland	8.7
In sun on woodland	8.3
In shade of plants on prairie	8.2
In sun on prairie	10.1

Should further inquiry prove that sun-dried squares are the most highly parasitized, another reason is presented for wide rows.

GEOGRAPHICAL CONSIDERATIONS.

By far the most important facts established by the table of percentage of parasitism (Table IV) were elicited by using the geographical map of Texas, published in the census of 1880, as a base.

I. The alluvial prairie of the Rio Grande is represented by Brownsville with an average percentage of parasitism in all forms of 6.1.

II. The coast prairie is represented by Corpus Christi with 8.5 per cent, Goliad with 8.0 per cent, Cuero with 5.5 per cent, and Victoria with 3.7 per cent.

III. The Edwards plateau is represented by Junction with 8.2 per cent, Roosevelt with 6.9 per cent, and 16 miles south of Roosevelt with 2.2 per cent. This latter case was a farm with very rank growth of cotton, from which shaded squares were picked on the ground. The weevil had not been present long.

IV. The black prairie is represented by Kerrville with 3.3 per cent, Taylor with 2.6 per cent, Corsicana (IVb) with 6.0 per cent, and Dallas with 5.1 per cent.

V. The cross timbers are represented by Waco with 11.4 per cent.

VI. The eastern hardwoods are represented on the south by Beeville with 1.2 per cent, Hallettsville with 2.8 per cent, each at the tip of an extension of this region, and by Calvert with 2.1 per cent, Palestine 3.7 per cent, Mineola 2.0 per cent, Overton 1.9 per cent, Marshall 8.0 per cent, Mansfield, La., 2.9 per cent, Many, La., 3.8 per cent. Marshall is probably represented by a field on a red-land knoll, which would account for the discrepancy.

VII. The eastern pine country is represented by Trinity with 2.4 per cent, and Orange, La., with 0.9 per cent. Trinity is in a transitional region of pines and hardwoods, but seems to belong more typically to the hardwood region.

It will be readily observed that regions I, II, III, V, with Corsicana in IVb, which really belongs to the brown loam region in the eastern hardwoods, and Marshall in VI, which belongs to the red-land areas of the eastern hardwoods, are the most highly parasitized, while the regions IV, VI, and VII are the lowest parasitized.

The map on the opposite page (fig. 4) is presented to illustrate these statements.

While it may be merely a coincidence that the places in the same belt have about the same proportion of parasitism, it is nevertheless worthy of some attention. It is undoubtedly true that each of these floral regions is also a distinct subfaunal region. It may therefore be expected that different weevils will exist in the different belts and different parasites operate upon these weevils. Some of these parasites may be able more readily than others to adopt the boll weevil as a host, or in certain regions there may be more species of parasites capable of doing this. In the discussion of the geographical distribution of the parasites more light will be thrown upon this question.

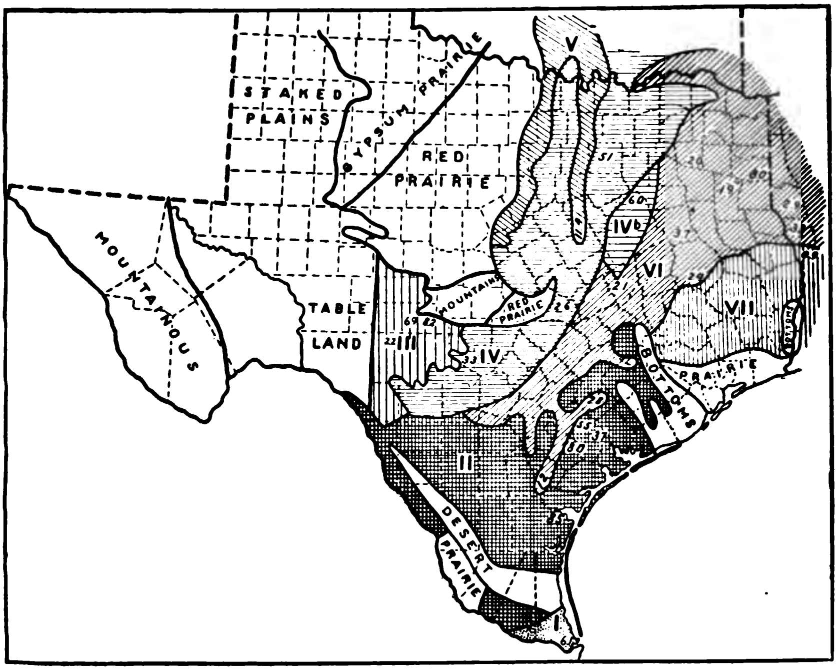

FIG. 4.—Map of Texas, divided into geographical regions and illustrating average percentage of parasitism of the boll weevil in all cotton forms: I, alluvial prairie; II, coast prairie; III, Edwards Plateau; IV, black prairie; IVb, brown loam prairie; V, cross timbers; VI, oak, hickory, and pine; VII, pines. (Original.)

BOLL WEEVIL STATUS.

That there should be some definite relation between the percentage of infestation and the percentage of parasitism was expected, on the ground that a condition favorable to the weevil should be favorable to the parasites. It was, of course, conceded that climate would be another agency to figure in the question. The year's work is deficient in that coordinate examinations of infestations and parasitism were not taken. In another year this will be necessary in order to show whether the parasites are reducing the infestation.

At present no relation can be found between parasitism and infestation or climatology. Beeville, Goliad, and Victoria have a mean annual temperature of 70° and a precipitation of 30 inches. At Beeville the average percentage of parasitism in fallen squares was 1.3 per cent, at Goliad 8.5 per cent, at Victoria 3 per cent. This condition occurs throughout the entire State. At Calvert the percentage of infestation of squares on August 28 was 55.6 per cent and at Goliad it was 20.9 per cent, and yet the average percentage of parasitism in fallen squares at Calvert was 1.4 per cent and Goliad 8.5 per cent. A reverse condition may be cited as follows: At Cuero the percentage of infestation of squares on August 28 was 74 per cent and at Victoria it was 32.7 per cent, and the average percentage of parasitism in hanging squares at Cuero was 19.9 per cent and at Victoria 10.2 per cent. Table XII gives in detail the irregularity displayed between these three factors.

TABLE XII.—*Boll weevil status and parasitism.*

Locality.	Mean annual temperature.	Mean annual precipitation.	First examination, July 3, 1906.		Weevil status, Aug. 28, 1906.		Average parasitism, 1906.			
			Average per acre.		Percentage infested.		Squares.		Bolls.	
			Plants.	Weevils.	Squares.	Bolls.	Fallen.	Hanging.	Fallen.	Hanging.
Brownsville, Tex	72	25					6.5		3.3	
Corpus Christi, Tex	70	30	9,412	212	71.0	84.0	9.0		0.0	
Beeville, Tex	70	30	8,859	300	21.8	3.1	1.3		0.0	
Goliad, Tex	70	30	10,169	305	20.9	1.6	8.5	13.8	2.2	4.9
Victoria, Tex	70	30	8,334	119	32.7	15.0	3.0	10.2	0.0	.5
San Antonio, Tex	68	25	12,186	101	38.0	.2	0.0			
Yorktown, Tex	68	30			67.2	20.5				
Cuero, Tex	68	30	7,225	135	74.0	59.0	1.0	19.9	0.0	1.0
Hallettsville, Tex	68	30	8,056	289	78.0	3.2	.4	9.2	1.0	3.7
Austin, Tex	68	30	15,580	73	19.2	.27				
Giddings, Tex	68	30	15,600	76	34.5	2.1				
Lula, Tex	66	25					0.0			
Sixteen miles south of Roosevelt, Tex	66	25					2.4			
Roosevelt, Tex	66	25					14.4		0.0	
Junction, Tex	66	25					8.2		5.8	
Mountain Home, Tex	66	25					0.0			
Kerrville, Tex	66	25					10.5		2.3	
Bryan, Tex	68	40	10,170	38	52.3	4.1				
Hempstead, Tex	68	40	12,255	84	74.7	10.5				
Eagle Lake, Tex	68	40	5,735	89	20.8	13.0				
Wharton, Tex	68	40	5,127	93	54.0	17.3				
Taylor, Tex	66	30					.6	5.0	1.5	2.5
Cameron, Tex	66	30	16,317	67	73.3	46.0				
Waco, Tex	66	30	13,800	49	68.7	6.2	8.4	27.3	1.7	11.1
Hillsboro, Tex	66	30	18,200	0	4.8	3.4				
Corsicana, Tex	66	30	20,524	0	38.0	1.4	0.0	11.7	5.9	3.4
Mexia, Tex	66	30	18,520	0	.8	0.0				
Calvert, Tex	66	40	11,377	196	55.6	8.0	1.4	9.8	0.0	6.6
Palestine, Tex	66	40	12,712	61	52.8	14.4	1.2	11.5	.4	3.3
Athens, Tex	66	40	11,568	21	21.6	1.7				
Troupe, Tex	66	40	8,126	390	92.0	67.5				
Jacksonville, Tex	66	40	10,963	160	70.0	32.0				
Henderson, Tex	66	40	7,536	564	87.6	52.8				
Dallas, Tex	64	40			22.5	0.0	0.0	4.6	0.0	5.9
Terrell, Tex	64	40	14,000	0	0.0	0.0	0.0		0.0	
Mineola, Tex	64	40	1,607	105			2.0		1.8	
Marshall, Tex	66	50	9,480	69	78.0	29.0	0.0	16.6	0.0	13.5
Trinity, Tex	68	50	9,990	182	50.8	11.0	1.2	12.4	.4	10.3
Lufkin, Tex	68	50	11,320	36	53.2	10.7				
Overton, Tex	68	50	7,780	69	78.0	29.0	1.0	2.2	0.0	4.5
Fort Towson, Ind. T	64	50		0	0.0	0.0		0.0		0.0
Kosoma, Ind. T	64	50		0	0.0	0.0		0.0		0.0
Mansfield, La	68	50					.6	2.9	0.0	5.9
Many, La	68	50					.4	10.4	1.5	5.9
Orange, La	68	50					1.1		0.0	
Minden, La	66	50		0	0.0	0.0		.5		
Johnsons Bayou, La	70	50					0.0			

BOLL WEEVIL CHRONOLOGY.

The boll weevil has been present in the United States since 1892. Year by year it has extended its ravages, although during the summer of 1896 and the winter of 1904–5 it received severe setbacks. Its territory now extends into four States, and in three of these observations as to parasitism were made. Several examinations were made immediately after the dispersion of August in newly infested fields, and at Minden, La., it was actually found that parasitization had commenced within two weeks of the weevil's arrival. The parasites do not follow the weevil; they are already present and native to the country invaded. Thus it is that in some parts of Texas where the weevil has been present ten or more years the parasites have not as great a hold as they have at Waco, which has only had it four years. There are probably more sources for parasites at Waco than at other points.

TABLE XIII.—*Weevil chronology and parasitism.*

Locality.	Chronology.	Average parasitism.			
		Squares.		Bolls.	
		Fallen.	Hanging.	Fallen.	Hanging.
Minden, La	Weevil arrived in the August dispersion of 1906. First generation in green squares collected.		.5		
Fort Towson, Ind. T	do		0.0		
Kosoma, Ind. T	do		0.0		
Lula, Tex	Weevil arrived in 1906, probably	0.0			
Sixteen miles south of Roosevelt, Tex.	Weevil arrived in 1905 or 1906	2.4			
Roosevelt, Tex	Weevil arrived in 1905	14.4		0.0	
Junction, Tex	do	8.2		5.8	
Mountain Home, Tex	do	0.0			
Kerrville, Tex	Weevil arrived in 1904 or 1905	10.5		2.3	
Dallas, Tex	Weevil arrived in 1904; set back February, 1905; rearrived 1905.	0.0	4.6	0.0	5.9
Mineola, Tex	do	2.0		1.8	
Terrell, Tex	do	0.0		0.0	
Johnsons Bayou, La	Weevil arrived in the August dispersion of 1904.	0.0			
Mansfield, La	do	.6	2.9	0.0	5.9
Marshall, Tex	do	0.0	16.6	0.0	13.5
Overton, Tex	do	1.0	2.2	0.0	4.5
Many, La	Weevil arrived in the fall of 1903	.4	10.4	1.5	5.9
Corsicana, Tex	Weevil present in 1903	0.0	11.7	5.9	3.4
Waco, Tex	Weevil present in 1902	8.4	27.3	1.7	11.1
Trinity, Tex	Weevil present in 1901	1.2	12.4	.4	10.3
Palestine, Tex	do	1.2	11.5	.4	3.3
Calvert, Tex	do	1.4	9.8	0.0	6.6
Taylor, Tex	do	.6	5.0	1.5	2.5
Hallettsville, Tex	Weevil present in 1897	.4	9.2	1.0	3.7
San Antonio, Tex	Weevil arrived in 1894; set back until 1897.	0.0			
Cuero, Tex	Weevil arrived in 1895; set back until 1896.	1.0	19.9	0.0	1.0
Victoria, Tex	do	3.0	10.2	0.0	.5
Goliad, Tex	Weevil present in 1894	8.5	13.8	2.2	4.9
Corpus Christi, Tex	Weevil present in 1893	9.0		0.0	
Beeville, Tex	do	1.3		0.0	
Brownsville, Tex	Weevil present in 1892	6.5		3.3	

CONCLUSIONS.

A few points of practical importance have been deduced from the foregoing general tables.

1. Inasmuch as the parasites are known to attack the weevil in its first generation in a newly infested locality, it may be expected that by releasing the proper parasites in a given locality the percentage of parasitism may be increased in a very short time. Such a case was actually obtained by the release of *Bracon mellitor* at Dallas, as described in the section on propagation.

2. Dryness and sunlight assist attack by the chalcidoid and braconid parasites of the weevil, as proved by the following considerations: (It is, of course, to be understood that this conclusion may hold only for those species and regions studied. In fact two or three of the minor species, such as the tachinids, give promise of doing most favorable work under directly opposite conditions in regions so far unstudied.)

a. Stages in hanging forms are, as a rule, parasitized to a higher degree than those in fallen forms.

b. Stages in fallen forms on prairie land are generally more highly parasitized than those in wooded country, although frequently hanging forms in wooded country are more highly parasitized than those in prairie land.

c. Fallen and hanging forms on unshaded ground are more highly parasitized than those on shaded soil.

These facts give an added importance to certain cultural methods already advocated, viz:

a. That the rows should be far apart, in order to allow the sun to dry the squares on the ground.

b. That determinate varieties should be planted in order to give additional heat and light for the parasites during the cooler autumn months.

That, as indicated by the present studies, dryness seems to be a most favorable condition for attack by hymenopterous parasites is quite natural, as these delicate little insects are very fond of sunlight and warmth.

II. Propagation Work.

1. INTERIOR WORK — TRANSFER OR ARTIFICIAL PROPAGATION OF PARASITES.

It has not been a difficult matter to breed the parasites of the boll weevil. There have been used in this laboratory four distinct methods of obtaining parasites, all of which served the purpose for which they were used. In all cases where definite records of percentage, length of stages, or nature of parasitism were required there has been a careful examination of each form (square or boll), and those forms containing parasites, or sometimes only the parasite and its host, were placed in individual pill bottles, numbered, recorded, and placed in trays for daily observation. A somewhat less exact method has been to place a limited number of squares in a tumbler on moist or dry soil in order to make the time of development more nearly normal. These tumblers were covered with cheese cloth and tagged.

When definite records were not requisite large quantities of squares or bolls were placed in Riley breeding cages and the parasites were obtained in larger quantities with less mortality, which is frequently caused by rough handling in the closer examinations. Closed boxes with numerous tubes on one side, after the pattern of the parasite breeding cages adopted by the California board of horticulture, were also used for small quantities of squares. These cages probably hasten development by increasing the heat and moisture.

There was, however, another problem which proved beyond solution for this season. It may be described as the effort to induce the parasites to attack the stages in forms placed in cages of various kinds. No positive results were obtained, but considerable experience was gained in the matter of breeding-cage technique.

The first work was done with various kinds of glassware, closed with cheese cloth. As fast as males and females of the same species could be bred they were isolated in pairs and placed with a limited number of infested squares. These squares were fresh, flared, or fallen, in order to test all conditions.

Glass tumblers covered with cheese cloth proved too dark. When dry earth was placed in the tumbler or when there was no earth, the squares rapidly dried and became very hard, and the parasites quickly died. When moistened earth was used the squares quickly molded and the parasites were killed by the fungus. When a water reservoir was sunk in the earth the parasites drowned.

When glass lamp chimneys were placed on clay saucers filled with moist soil there was plenty of light and the material remained in good condition. The objection to this method is that the parasites can not be easily handled.

Erlenmyer flasks gave plenty of light and were easy to handle as they have a small mouth, but they sweat profusely and the parasites were caught in the moisture on the glass. Blotters, absorbent cotton, and corks with large wire-covered openings failed to prevent the sweating.

The last attempt on this line was with mica lamp chimneys such as are used with the ordinary incandescent gas burners. These were covered at both ends with cheese cloth. They are of light weight, give plenty of sunshine and sufficient circulation. For a small breeding cage they are very handy in many ways. But the parasites did not attack the weevil even in these cages.

In all of the above types of cages the life of the parasite was hardly a day. In wire types of cages the parasites lived several days. In the following, several of each sex of the parasites were used.

The first type was a cubic cage made very easily by using strips of cork for the framework and fine meshed wire (known as 50 to the inch, but really 35 and 45 to the inch) for the sides. One side was fixed with two openings which were closed on the inside by a tin shutter. The lower opening was round, and in this a cork with a glass tube through it was placed before the shutter was raised. Thus the parasites, being attracted to light, could be quickly removed by darkening the sides and allowing the light to enter only through the tube. When the shutter was raised higher it exposed a larger opening through which material could be passed.

With this first cage as a type various modifications were contrived, all with wire fronts, shutters of various kinds, and corked holes for the admission of a tube or for passing in small objects. Cigar boxes became the bases for these cages.

Still another modification was a wire cylinder corked at one end and with a smaller cork centered in this for the removal of material. The other end was covered with cheese cloth.

It was found impossible to provide plant conditions in a small cage unless the plant were actually transplanted or grown from seed. A branch of cotton withers so quickly that experiments of this sort were of no value.

Both kinds of tubes were tested on the plants, but the mica tube caused a heavy sweat and killed the branch it was on; the wire tube was too heavy. All of the plants placed under the large parasite-tight cages with glass sides died before results could be expected.

2. FIELD WORK—RELEASE OF PARASITES.

The release of parasites in the field was not commenced until September 12 on account of the small amount of material gathered prior to that date. Notwithstanding that fact the results give an indication of success. On the laboratory farm at the top of the hill there were released 35 parasites on September 12 and 38 on September 15. These parasites were of three species. An examination of hanging forms was made in this part of the field and another down the hill at the opposite side and about 350 yards distant. At this time the check area ("B," fig. 5) showed 1.9 per cent higher parasitism than the parasite area ("A," fig. 5). Twenty days later, on October 2, like examinations were made with the result that the percentages were reversed; "A" showed an increase of 2.6 per cent and "B" showed a decrease of 6.5 per cent; that is, "A" was 7.2 per cent more highly parasitized than "B" and showed a real gain in parasitism of 9.1 per cent. On October 6 this examination was followed by another, and, although the difference was less, "A" was 3.9 per cent more highly parasitized than "B." Plat "A" was next to a fence and separated from another field of cotton by a road and a high hedge of *Ambrosia trifida* with scattered *Solanum rostratum.* As a further check on the experiment the nearest part of this field ("D," fig. 5) was examined and proved to be parasitized by 2.1 per cent less than "A." On the contrary, the farther part of the field ("E," fig. 5) showed 5.8 per cent higher parasitism than "A." The conclusion was that "E" and "D" did not influence "A."

The results are given in Table XIV for the entire experiment, and also according to species. It is believed by the writer that it was the release of *Bracon mellitor* which accomplished the change.

The evidence upon which this belief is founded is both positive and negative. *Bracon mellitor* was not found breeding upon any other species of weevil in the vicinity, and yet the examinations showed an increase of parasitization by this species in the "parasite area" opposed to a decrease in the "check area." *Catolaccus incertus,* although released in large numbers, did not take hold at all, nor was it found breeding upon any other species of weevil in the vicinity. A few *Cerambycobius cyaniceps* were released, but the only trace of parasitization by this species was found in the original check. And yet this species was bred from *Lixus musculus* in the stems of *Polygonum pennsylvanicum* near by, and also from *Trichobaris texana* Lec., in the stems of *Solanum rostratum* adjacent to "A". No *Eurytoma tylodermatis* were released, although this species was abundant throughout the field. It is known as a parasite of *Lixus scrobicollis* Boh., which breeds in *Ambrosia trifida* stems. Immense numbers of this plant were growing along the road adjacent to "A." In order to show that plat "E," which was highly parasitized by

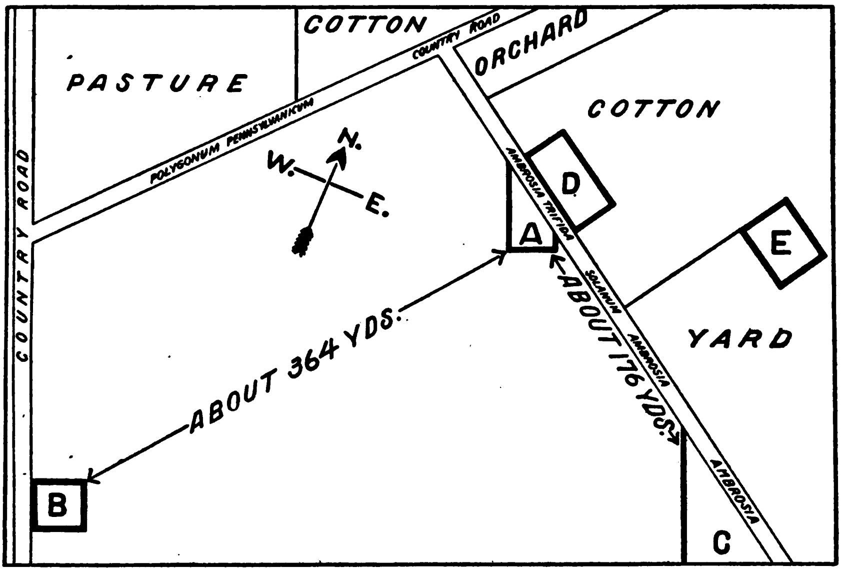

FIG. 5.—Diagram of cotton plantation of H. O. Samuel, Dallas, Tex., of 644 acres, showing location of plats where observations and experiments on boll-weevil parasitism were made. (Original.)

Bracon mellitor, did not influence the numbers of that species in "A," the fact may be cited that the higher percentage of *Eurytoma tylodermatis* in "E" evidently had no influence upon the presence of that species in "A."

TABLE XIV.—*Release of parasites of the boll weevil—Summary of all species.*

Date.	"A." Parasite area.			"B." Check area.			"C." Check area.			"D." Area across road.			"E." Area 100 yards from "D."			Total.		
	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.
Sept. 12	120	7	5.8	180	14	7.7	.....	.....	.....	.....	.....	.....	.....	.....	.....	300	21	7.0
	Released 27 ♀, 8 ♂.																	
Sept. 15	Released 35 ♀, 3 ♂.																	
Oct. 2	95	8	8.4	163	2	1.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	258	10	3.8
Oct. 6	183	13	7.1	125	4	3.2	.....	.....	.....	218	11	5.0	96	11	12.9	622	39	6.2
Oct. 10	.....	.....	.....	.....	.....	.....	247	5	2.02	.....	.....	.....	.....	.....	.....	247	5	2.0

TABLE XV.—*Release and parasitism of Bracon mellitor.*

Date.	"A." Parasite area.			"B." Check area.			"C." Check area.			"D." Area across road.			"E." Area 100 yards from "D."			Total.		
	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.
Sept. 12	120	2	1.66	180	4	2.22	.....	.....	.....	.....	.....	.....	.....	.....	.....	300	6	2.0
	Released 14 ♀, 6 ♂.																	
Oct. 2	95	5	5.26	163	1	.61	.....	.....	.....	.....	.....	.....	.....	.....	.....	258	6	2.3
Oct. 6	183	6	3.27	125	1	.80	.....	.....	.....	218	7	3.22	96	5	5.21	622	19	3.0
Oct. 10	.....	.....	.....	.....	.....	.....	247	5	2.02	.....	.....	.....	.....	.....	.....	247	5	2.0

TABLE XVI.—*Release and parasitism of Catolaccus incertus.*

Date.	"A." Parasite area.			"B." Check area.			"C." Check area.			"D." Area across road.			"E." Area 100 yards from "D."			Total.		
	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.
Sept. 12	120	0	0.0	180	4	2.22	.....	.....	.....	.....	.....	.....	.....	.....	.....	300	4	1.3
	Released 10 ♀, 2 ♂.																	
Sept. 15	Released 30 ♀, 1 ♂.																	
Oct. 2	95	0	0.0	163	0	0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	258	0	0.0
Oct. 6	183	1	.54	125	0	.0	.....	.....	.....	218	0	0.0	96	0	0.0	622	1	0.1
Oct. 10	.....	.....	.....	.....	.....	.....	247	0	0.0	.....	.....	.....	.....	.....	.....	247	0	0.0

TABLE XVII.—*Release and parasitism of Cerambycobius cyaniceps.*

Date.	"A.". Parasite area.			"B." Check area.			"C." Check area.			"D." Area across road.			"E." Area 100 yards from "D."			Total.		
	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.
Sept. 12......	120	0	0.0	180	1	0.55	.....	.....	.....	.....	.....	.....	.....	.....	.....	300	1	0 3
	Released 3 ♀.																	
Sept. 15......	Released 5 ♀, 1 ♂.																	
Oct. 2........	95	0	.0	163	0	0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	258	0	0.0
Oct. 6........	183	0	.0	125	0	.0	.....	.....	.....	218	0	0.0	96	0	0.0	622	0	0.0
Oct. 10......	.....	.....	.....	.....	.....	.....	247	0	0.0	.....	.....	.....	.....	.....	.....	247	0	0.0

TABLE XVIII.—*Parasitism of Eurytoma tylodermatis.*

Date.	"A." Parasite area.			"B." Check area.			"C." Check area.			"D." Area across road.			"E." Area 100 yards from "D."			Total.		
	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.
Sept. 12.....	120	0	0.0	180	3	1.66	.....	.....	.....	.....	.....	.....	.....	.....	.....	300	3	1.0
Oct. 2........	95	2	2.10	163	0	.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	258	2	0.7
Oct. 6........	183	1	.54	125	1	.80	.....	.....	.....	218	2	0.91	96	6	6.25	622	10	1.6
Oct. 10......	.....	.....	.....	.....	.....	.....	247	0	0.0	.....	.....	.....	.....	.....	.....	247	0	0.0

III. PARASITE BREEDING WORK.

Four new primary parasites of the boll weevil have been bred this year, and several definite cases of predaceous attack have been observed. There are now known 11 primary hymenopterous parasites, 1 primary dipterous parasite, 2 acarid parasites (at least), 2 coleopterous enemies, and 2 ant enemies which attack the weevil stages in the cotton forms. They are as follows (insects which attack the adult weevils are omitted from the consideration):

PRIMARY PARASITES.

Hymenoptera.
  Chalcidoidea.
    Torymidæ, Monodontomerinæ.
      1. *Microdontomerus anthonomi* Cwfd. (Texas).
    Eurytomidæ.
      2. *Eurytoma tylodermatis* Ashm. (Mexico, Texas, Louisiana).
      3. *Bruchophagus herreræ* Ashm. (Mexico).
    Encyrtidæ, Eupelminæ.
      4. *Cerambycobius cyaniceps* Ashm. (Louisiana, Texas).
    Pteromalidæ, Pteromalinæ.
      5. *Catolaccus incertus* Ashm. (Texas, Louisiana).

Hymenoptera—Continued.
  Ichneumonoidea.
    Braconidæ, Sigalphinæ.
      6. *Sigalphus curculionis* Fitch (Texas).
      7. *Urosigalphus anthonomi* Cwfd. (Texas, probably Mexico).
      8. *Urosigalphus schwarzi* Cwfd. (Guatemala).
    Braconinæ.
      9. *Bracon mellitor* Say (Mexico, Texas).
      10. *Bracon dorsator* Say (Texas).
      11. Undetermined braconid (Texas).
Diptera.
    Tachinidæ.
      12. *Myiophasia ænea* Wied. (Texas, Louisiana).
Acarina.
      13. *Pediculoides ventricosus* Newp. (Mexico).
      14. *Tyroglyphus breviceps* Banks (Texas).

PREDACEOUS ENEMIES.

Coleoptera.
    Cleridæ.
      15. *Hydnocera pubescens* Lec. (Texas, Louisiana).
    Cucujidæ.
      16. *Cathartus cassiæ* Reiche (Texas).
Hymenoptera.
  Formicoidea.
    Myrmicidæ, Myrmicinæ.
      17. *Solenopsis geminata* Fab. (Guatemala, Texas, Louisiana).
    Formicidæ, Formicinæ.
      18. *Formica fusca subpolita perpilosa* (Mexico).

HYPERPARASITES.

Hymenoptera.

Microdontomerus anthonomi Cwfd. *Eurytoma tylodermatis* Ashm. *Cerambycobius cyaniceps* Ashm.	Accidental on *Bracon mellitor* Say.

POSSIBLE PRIMARY PARASITES.

Hymenoptera.
      Catolaccus anthonomi Ashm. (Texas).

Two species of entomogenous fungi, *Aspergillus* sp. and *Cordyceps* sp., have been recorded as probably parasites of boll-weevil larvæ.

OCCURRENCE OF SPECIES.

1. *Microdontomerus anthonomi* Cwfd.[a] This species was collected as follows: Goliad, Tex., September 3, 1906, 1 bred from *Bracon mellitor* cocoon; Cuero, Tex., August 31, 1906, 1 bred from *Bracon mellitor* cocoon; Hallettsville, Tex., August 30, 1906, 4 females, primary parasites upon *A. grandis;* Waco, Tex., August 28, 1906, 2 females, primary parasites upon *A. grandis;* Waco, Tex., August 29, 1906, 1 male, 3 females, primary parasites upon *A. grandis;* Waco, Tex. August 29, 1906, 1 male, bred from *Bracon mellitor* cocoon.

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[a] Crawford, 1907a, b.

The range of the Microdontomerus is evidently western. Twenty-three per cent were secondary parasites.

2. *Eurytoma tylodermatis* Ashm. This species, while not very important in any part of the State, is very well distributed. It was recorded continuously after July 12, 1906. Specimens were bred from material collected at Beeville, Brownsville, Calvert, Cuero, Dallas, Goliad, Hallettsville, Overton, Palestine, Trinity, Victoria, and Waco, Tex., and at Mansfield and Many, La. No records were obtained from Corpus Christi, Corsicana, Junction, Kerrville, Lula, Marshall, Mineola, and Taylor, Tex.; nor from Orange, La. Specimens were sent in by Prof. A. L. Herrera from Allende, Coahuila, Mexico, with the note that it was abundant at that place.

3. *Bruchophagus herreræ* Ashm. This parasite has not been taken in the United States. It was described from Coahuila, Mexico.

4. *Cerambycobius cyaniceps* Ashm. This parasite has been taken at all points investigated except those in the Edwards Plateau region.

5. *Catolaccus incertus* Ashm. This parasite has not been taken at Overton or Marshall in northeastern Texas, but is common at all other points investigated.

6. *Sigalphus curculionis* Fitch has not been recorded since the first specimen was bred at Calvert, Tex.

7. *Urosigalphus anthonomi* Cwfd.[a] One female was bred from a cocoon in a weevil cell from material collected September 5 at Brownsville, Tex. As the former record was also from Brownsville, this species may be taken to be Mexican in origin.

8. *Urosigalphus schwarzi* Cwfd.[a] From 300 squares Mr. E. A. Schwarz and Mr. H. S. Barber bred 5 females and 1 male of this newly described species at Cacao, Finca Trece Aguas, Alta Vera Paz, Guatemala, during April, 1906.

9. *Bracon mellitor* Say was bred from all points, except Overton and Marshall in northeastern Texas. The form known as *Bracon xanthostigma* has only been bred from the weevil between September 16 and April 28 in the various years of this investigation. A specimen of this species is recorded on the Bureau of Entomology files (D. A. 6424 (412)) as bred from the boll weevil at Coahuila, Mexico, November 15, 1902, by Professor Herrera. Specimens were sent in by Professor Herrera from Allende, Coahuila, Mexico, during 1906, with the notes that they were quite common.

10. *Bracon dorsator* Say was not bred until October in 1906. It is only known to occur between August 2 and December 17 in Texas. It is probably another instance of seasonal dimorphism and identical with *Bracon mellitor*.

11. Braconid. One female of this species was bred September 1 from a cocoon in material collected on the ground at Victoria, Tex. The specimen was lost in transit.

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[a] Crawford, 1907a.

12. *Myiophasia ænea* Wied. Pupæ of this species within the larval skin of the weevil were taken from material collected at Many, La. (3 specimens), and Waco, Tex. (1 specimen); also one specimen in imperfect condition was found in a small boll collected at Victoria, Tex., July 12. Its puparium was within the skin of a weevil larva.

13. *Pediculoides ventricosus* Newp. is a common weevil parasite in Mexico.

14. Mites were frequently found to have destroyed the weevil stages in fallen squares, especially at Calvert, Tex.

Tyroglyphus breviceps Banks was described as a weevil enemy from Victoria, Tex.

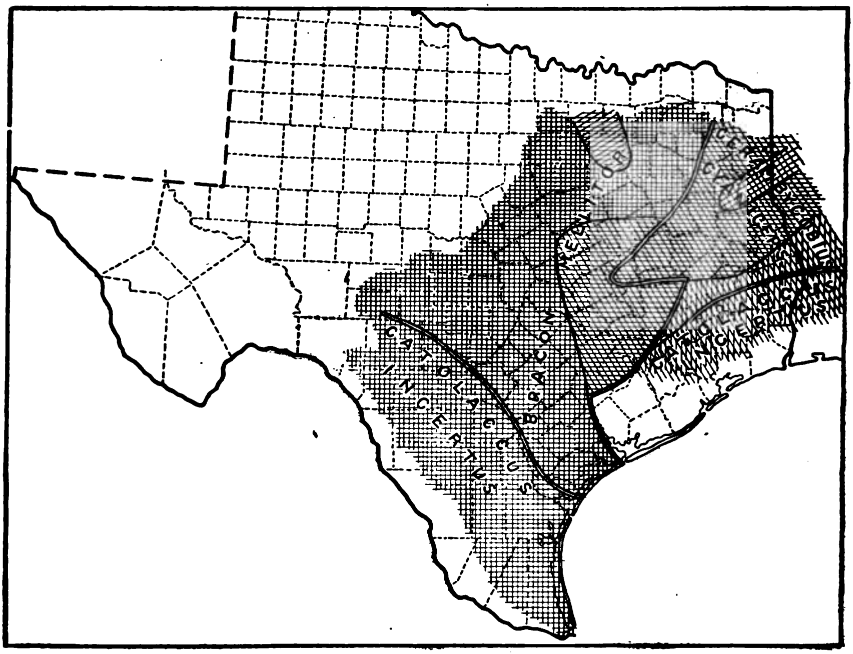


FIG. 6.—Occurrence of predominant parasites of the boll weevil in Texas and western Louisiana showing—
|| Occurrence of *Catolaccus incertus*. ≡ *Bracon mellitor*. \\\\ *Cerambycobius cyaniceps*. //// *Eurytoma tylodermatis*. // Limits of predominance of single species. / Limits of two predominant species. (Original.)

15. *Hydnocera pubescens* Lec. was found frequently to have killed weevil stages. Records of this predatory habit are from Brownsville and Waco, Tex., and Many, La. In a great many other cases evidence of its predatory nature was less reliable.

16. *Cathartus cassiæ* Reiche was found several times to be predaceous in its larval stage upon the weevil.

Catolaccus anthonomi Ashm., determined by J. C. Crawford. Four specimens practically identical in character with the type of this species were bred from cotton squares collected October 12, 1906, at

Waco, Tex. Although a large quantity of these squares were examined, no specimens of this species were obtained except from the general breeding cage. The species is known as a parasite of an æstivating weevil (*Anthonomus signatus* Say), and it is possible that in the fall the parasites may attack *Anthonomus grandis*.

GEOGRAPHICAL AND SEASONAL DISTRIBUTION OF PARASITES.

Only four of these parasites are at present of any great importance. In arranging the percentages of each species with regard to the total number of parasites the following table (Table XIX) has brought out sufficient data for the production of a map (fig. 6) which shows the area over which any two of them are predominant. Thus, over the entire western half of the area studied *Bracon mellitor* and *Catolaccus incertus* are the most active, while in the Northeast and East *Cerambycobius cyaniceps* shares the importance with the other three in more or less limited belts:

TABLE XIX.—*The seasonal distribution of the parasites.*

Locality.	Date.	Total number of parasites.	Bracon mellitor.		Catolaccus incertus.		Eurytoma tylodermatis.		Cerambycobius cyaniceps.	
			Number.	Percentage.	Number.	Percentage.	Number.	Percentage.	Number.	Percentage.
	1906.									
Beeville, Tex.	July 12	26	8	30.7	5	19.2	2	7.6	1	3.8
Do	August 8	2	2	100.0	......	......	......	......	......	......
Do	August 13	2	......	......	......	......	......	......	......	......
Do	September 3	6	6	100.0	......	......	......	......	......	......
Brownsville, Tex.	July 5	43	38	88.3	5	11.7	......	......	......	......
Do	July 28	119	39	32.7	77	64.7	3	2.6	......	......
Do	August 3	2	......	......	......	......	......	......	......	......
Do	September 5	155	50	32.2	85	54.8	1	0.6	2	1.2
Do	September 29	53	12	22.6	40	75.4	......	......	......	......
Calvert, Tex.	August 28	13	3	23.0	3	23.0	1	7.6	4	30.7
Do	September 13	21	3	14.2	......	......	......	......	4	19.0
Corpus Christi, Tex.	July 10	39	9	23.0	12	30.7	1	2.5	......	......
Corsicana, Tex.	August 23	19	9	47.3	4	21.0	1	5.2	......	......
Do	September 18	2	1	50.0	......	......	......	......	......	......
Cuero, Tex.	August 9	13	3	23.0	2	15.3	......	......	1	7.6
Do	August 31	87	45	51.7	25	28.7	6	6.8	4	4.5
Dallas, Tex.	August 29	1	......	......	......	......	......	......	......	......
Do	September 12	21	6	28.5	4	19.0	3	14.2	1	4.7
Do	October 2	10	6	60.0	......	......	2	20.0	......	......
Do	October 6	39	19	48.4	1	2.5	9	23.0	......	......
Do	October 10	5	5	100.0	......	......	......	......	......	......
Goliad, Tex.	August 7	7	......	......	......	......	......	......	......	......
Do	September 3	108	73	67.5	22	20.3	3	2.7	2	1.8
Hallettsville, Tex.	August 9	15	3	20.0	3	20.0	2	13.3	1	6.6
Do	August 30	39	7	17.9	4	10.2	7	17.9	8	20.4
Junction, Tex.	September 24	12	10	83.3	2	16.7	......	......	......	......
Kerrville, Tex.	August 26	6	3	50.0	2	33.3	......	......	......	......
Do	September 3	5	2	40.0	1	20.0	......	......	......	......
Mansfield, La.	August 24	47	5	10.6	2	4.2	1	2.1	36	76.5
Many, La.	August 23	109	6	5.5	12	11.0	8	7.3	45	41.2
Marshall, Tex.	August 22	8	......	......	......	......	......	......	6	75.0
Mineola, Tex.	August 10	1	......	......	......	......	......	......	......	......
Do	October 2	9	4	44.4	4	44.4	......	......	......	......
Orange, La.	September 30	5	......	......	4	80.0	......	......	......	......
Overton, Tex.	August 23	7	......	......	......	......	1	14.2	2	28.4
Palestine, Tex.	August 10	70	12	17.1	10	14.2	6	8.5	7	10.0
Roosevelt, Tex.	September 24	10	5	50.0	......	......	......	......	......	......
Sixteen miles south of Roosevelt, Tex.	September 25	2	......	......	1	50.0	......	......	......	......
Taylor, Tex.	August 16	11	3	27.2	......	......	2	18.1	......	......
Trinity, Tex.	August 9	69	12	17.3	9	13.0	7	10.1	12	17.3
Do	August 30	14	1	7.1	5	35.7	......	......	2	14.2

TABLE XIX.—*The seasonal distribution of the parasites*—Continued.

Locality.	Date.	Total number of parasites.	Bracon mellitor.		Catolaccus incertus.		Eurytoma tylodermatis.		Cerambycobius cyaniceps.	
			Number.	Percentage.	Number.	Percentage.	Number.	Percentage.	Number.	Percentage.
	1906.									
Victoria, Tex	June 16	15	......	......	......	......	......	......	......	......
Do	June 23	9	5	55.5	2	22.2	......	......	......	......
Do	June 25	11	2	18.0	6	54.5	......	......	......	......
Do	June 26	20	10	38.4	7	26.9	......	......	......	......
Do	June 27	33	15	45.4	8	24.2	1	3.0	......	......
Do	June 28	24	......	......	......	......	......	......	......	......
Do	July 2	24	......	......	......	......	......	......	......	......
Do	July 5	19	......	......	......	......	......	......	......	......
Do	July 9	13	3	23.0	......	......	......	......	......	......
Do	July 18	32	18	56.2	2	6.2	1	3.1	......	......
Do	July 22	5	3	60.0	......	......	......	......	......	......
Do	September 1	75	45	60.0	3	4.0	3	4.0	11	14.6
Waco, Tex	July 25	78	25	32.0	6	7.6	3	3.8	4	5.1
Do	August 17	5	1	20.0	1	20.0	1	20.0	......	......
Do	August 28	83	44	54.2	......	......	7	8.4	25	29.8
Do	August 29	114	64	56.1	11	9.6	3	2.6	12	10.5
Do	September 19	36	19	52.7	2	5.5	8	22.2	20	55.5
Do	October 12	31	......	......	......	......	......	......	......	......

These figures show very plainly the range of each species and have therefore been used to form a map of the two predominant species throughout the State. The centers of the areas predominated by Catolaccus are Brownsville, Tex., and Orange, La. The influence of Bracon radiates from Goliad and Corsicana, Tex. The center of predominance for Cerambycobius is Marshall, Tex. Eurytoma becomes an active agency at Dallas and Overton, Tex.

BIOLOGICAL NOTES ON THE PARASITES.

1. *Microdontomerus anthonomi* Cwfd. The Torymidæ have always been considered by Dr. William H. Ashmead as parasitic on Diptera. In addition to the records of parasitism upon the boll weevil, which are given on a preceding page, one other specimen was bred September 13, 1905, at Mexia, Tex., by F. C. Pratt from *Brachytarsus alternatus* Say, breeding in the stems of *Sideranthus rubiginosus*. The species is not at all abundant, and has only been collected in cotton forms between August 28 and September 3. It is perhaps a one-generation species, although it may have some other and still unknown host. There is but one individual to each host, and the host may be in the larval or pupal state when attacked. The sexes occurred in the proportion of 2 males and 11 females.

In order to ascertain the length of the developmental periods, the following scheme had to be used: The maximum period from collection to maturity is the nearest approach possible to the total developmental period, and next to this is the total period in a Bracon cocoon in case of hyperparasitism. The maximum period from the observation of the larva to maturity is the nearest approach possible to the total period passed as larva and pupa. The exact length of the pupal period may be defined as between the maximum period from observation of the pupa to maturity and the minimum period from observation of the larva to maturity. Thus it will appear from the following that the total developmental period is over twenty-three days, and the pupal stage lasts from six to nine days during August and September.

TABLE XX.—*Length of developmental periods in Microdontomerus anthonomi.*

Locality.	Date.	Collection to maturity	Larva to maturity.		Pupa to maturity	In Bracon cocoon to maturity.	Development.		
		Maximum.	Minimum.	Maximum.	Maximum.	Maximum.	Total.	Larva + pupa.	Pupa.
	1906.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
Cuero, Tex.	August 31	14				9			
Goliad, Tex.	September 3	23				19	23+		
Hallettsville, Tex.	August 30	14	9	9	6				6
Waco, Tex.	August 28, 29	10	9	9	5	6			
							23+	23	6–9

It was impossible with a lens to find any characters to distinguish the larvæ of this species from any of the other chalcidoids, as all of the chalcidoid larvæ concerned in this report are finely, transversely lineolate and clad with a few hairs regularly placed in a line around the middle of each segment. The pupa is nearest in appearance to that of Cerambycobius. The female pupa is robust, brown until almost mature, with no darker spots on the dorsal abdominal segments, but with three longitudinal white lines and a transverse white line on each segment; the ovipositor is appressed to the dorsum and proportionately longer than in Cerambycobius. The exuvium is easily recognized by the form of the ovipositor and its brown color. (See figure of pupa and of chalcidoid larva, Pl. I, figs. 4, 7.)

A most interesting point in the biology of this parasite is the fact that a number of individuals were bred from Bracon cocoons. This is one of those phenomena which are here designated as accidental secondary parasitism—that is, where a natural primary parasite finds its host consumed by another parasite and in order to retain its hold on life is compelled to attack that parasite itself.

The breeding records of the parasite are as follows:

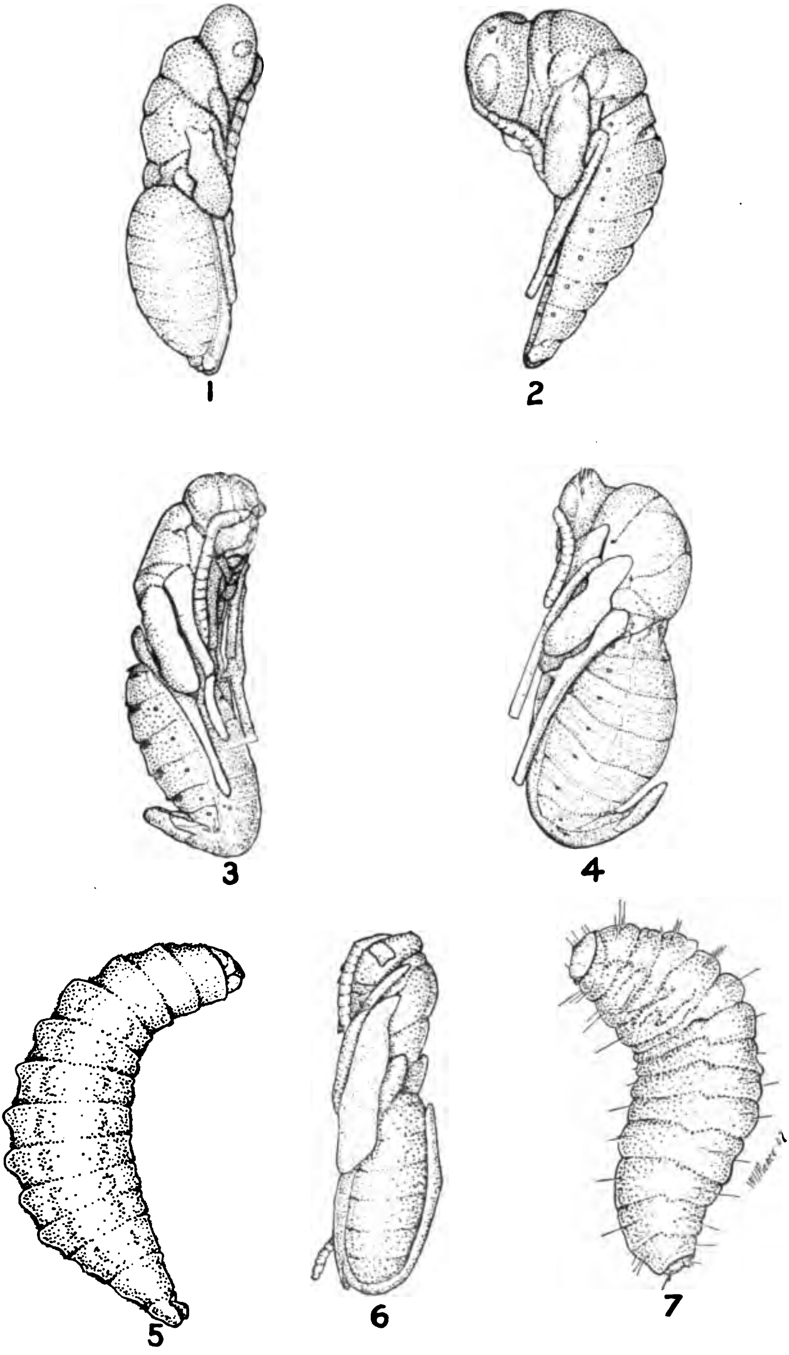
TABLE XXI.—*Breeding records of Microdontomerus anthonomi.*

Locality.	Date.	Total.		As primary parasites.		As secondary parasites.	
		Male.	Female.	Male.	Female.	Male.	Female.
	1906.						
Cuero, Tex	August 31		1				1
Goliad, Tex	September 3		1				1
Hallettsville, Tex	August 30		4		4		
Waco, Tex	August 28		2		2		
Do	August 29	2	3	1	3	1	
		2	11	1	9	1	2

Thirteen parasites were bred, of which 23 per cent were secondary. Owing to numerous expressions of incredulity concerning this dual parasitism it may be proper to state the proofs. In the first place, primary parasitism has been thoroughly established in the case of this species and also in the case of *Eurytoma tylodermatis* and *Cerambycobius cyaniceps*. Adults have been bred from larvæ which were actually observed to be feeding upon the weevil larvæ. The developmental period of those adults bred precludes any arguments that they were bred from unobserved eggs of parasites on the larvæ. In the second place, the Bracon and chalcidoid larvæ are very easily distinguished, so that the notes in most cases stated whether the larva observed was a Bracon or a chalcidoid. In no case was one of the latter bred from a Bracon except when the Bracon cocoon was already formed at the time of the observation. Finally, secondary parasitism was proved because the parasites were actually bred from isolated Bracon cocoons, which were subsequently opened and from which the known exuvia of the secondary parasites were removed.

2. *Eurytoma tylodermatis* Ashm. This species was bred by Townsend in 1895 and by Mally during several years from the boll weevil. Ashmead described it as a parasite of *Tyloderma foveolatum* Say (Ashmead, 1896), a weevil breeding in the stems of *Onagra biennis* and also in a species of Epilobium. It was reared by F. H. Chittenden from the larva of *Tyloderma foveolatum* Say in stems of *Onagra biennis*, September 23, from material collected at Rosslyn, Va.

This species was bred by the writer from *Anthonomus disjunctus* Lec. breeding in the heads of *Heterotheca subaxillaris* at Jacksonville, Tex., October 13, 1905 (1 male); from *Anthonomus squamosus* Lec., breeding in the heads of *Grindelia squarrosa nuda* at Clarendon, Tex., September 22, 1905 (6 females), and September 26, 1905 (2 males); from *Orthoris crotchii* Lec. breeding in the seed pods of *Mentzelia nuda* at Clarendon, Tex., October 2, 1905 (1 male); and from *Lixus musculus* Say, which forms galls in the stems of *Polygonum pennsylvanicum*, at Clarendon, Tex., October 2, 1905 (2 females), and October 17, 1905 (1 male). Mr. W. W. Yothers bred this Eurytoma from *Lixus*



PARASITES OF WEEVILS.

Fig. 1.—*Eurytoma tylodermatis*, pupa. Fig. 2.—*Catolaccus incertus*, pupa. Fig. 3.—*Cerambycobius cyaniceps*, pupa. Fig. 4.—*Microdontomerus anthonomi*, pupa. Fig. 5.—Larva of Bracon. Fig. 6.—*Bracon mellitor*, pupa. Fig. 7.—Larva of chalcidoid. Much enlarged. (Original.)

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scrobicollis, which breeds in great abundance in the stems of the common road weeds *Ambrosia trifida* and *A. psilostachya*, at Victoria, Tex., April 5, 1905 (1 female). In a personal letter dated August 30, 1906, Dr. Wm. H. Ashmead writes of this species: "*Eurytoma tylodermatis* Ashm. is another similar case [referring to his remarks on Cerambycobius, given later]. I have had several species of Eurytoma bred by Hopkins, Marlatt, etc., from beetles, and I can only quote their records. The genus seems to be primary and secondary as well as phytophagous, unless we can find characters to still further subdivide it generically."

This parasite is quite abundant throughout the season and is a continuous breeder. The number of generations is probably little less than that of the weevil. There is but one individual to each host, and the latter may be in the larval or pupal state when attacked. The sexes are in the proportion of 29.1 per cent male and 70.9 per cent female. The females are very much larger than the males.

Proceeding in the same manner as for the preceding species it is ascertained that the total developmental period is over 12 to 15 days, that the larval plus pupal period is over 11 to 14 days, and that the pupal period alone is at the minimum 6 days and maximum 13 days. Judging from this last period, for which the figures are definite, it may be safely said that the estimates for the larval and egg periods are very low. The increase in the length of the pupal period in October is noticeable.

The data upon the biology of *Eurytoma tylodermatis* are comparatively continuous from July 18 to October 19. In studying the length of the various stages the same methods were used as outlined for Microdontomerus. The only stage which could be definitely limited as to the period of development was the pupal stage, which was found to last from 7 to 8 days in the latter half of July, 6 to 9 days during August, 7 to 9 days in September, and 11 to 13 days in October.

The larvæ of Eurytoma were described in the notes as smooth, transversely lineolate, and with wrinklings at the sutures. The pupæ are white, pink-eyed, turning black toward maturity. They may be easily distinguished, by the lateral compression of the abdomen and the straight venter, from the pupæ of Catolaccus with their dorso-ventral compression and obtusely angulated venter. The exuvium is cast in parts and is never found intact as in the case of the other chalcidoids studied; the remains are yellowish transparent. (See figure of pupa, Pl. I, fig. 1.)

Secondary parasitism: One male was bred from material collected August 9 at Trinity, Tex., and two males from material collected September 19 at Waco, Tex., as secondary parasites in the cocoons of *Bracon mellitor*. In each case the cocoon was isolated when first found, so that no doubt could be expressed as to the source of the parasites. Corroboration was obtained by examining the cocoons.

3. *Bruchophagus herreræ* Ashm. Considerable doubt has been raised by very eminent parasitologists as to the actual parasitism of the boll weevil by this species and some doubt has been raised concerning its generic location. No subsequent corroboration has been obtained to prove parasitism of the boll weevil.

4. *Cerambycobius cyaniceps* Ashm. The first published record of the parasitism of the boll weevil by this species is found in Mally's Report (Mally, 1902), in which that writer states that he had bred it since 1899 at Austin, Tex. Only four records were obtained in previous years by the boll-weevil laboratory of the Bureau of Entomology; 1 female bred July 7 at Calvert, Tex., by G. H. Harris; 1 male and 1 female bred July 25 at Victoria, Tex., by W. E. Hinds, and 1 female bred March 11 at Corsicana, Tex., by C. M. Walker.

Dr. F. H. Chittenden has reared it from the larva of *Tyloderma foveolatum* breeding in the stems of *Onagra biennis*, September 11, from material collected at Chevy Chase, Md. He has also reared it from *Bruchus exiguus* Horn (Chittenden, 1893b). In a personal letter dated August 30, 1906, Dr. Wm. H. Ashmead said of this species: "It is not rare, has been bred from cerambycids and other beetles, and I have always supposed it to be a primary parasite. All of these beetles, however, have braconid parasites, and it may yet prove to be a secondary parasite as other of the eupelmines are said to be."

One female was bred by the writer October 17, 1905, as a probable parasite of *Lixus musculus* Say, breeding in stem galls of *Polygonum pennsylvanicum* collected September 19 at Clarendon, Tex. On October 26, 1906, a female was bred from a *Lixus musculus* pupa collected in the same plant at Dallas, Tex., opposite the farm on which release experiments were conducted. On September 11 and 12, 1906, 2 females were bred from *Anthonomus albopilosus* breeding in seed of *Croton engelmanni* collected August 26, 1906, at Johnsons Bayou, La., by J. D. Mitchell. On October 30, 1906, 1 female was bred from *Trichobaris texana* found breeding in stalks of *Solanum rostratum* by R. A. Cushman and the writer, along the road close to the plat upon which parasites were released at Dallas.

This parasite is very abundant in eastern Texas, diminishing to the Southeast, and is entirely absent at Brownsville and through western Texas. It is a continuous breeder, attacking the weevil larvæ and pupæ, one individual for each host. The sexes are in the proportion 19.7 per cent males and 80.3 per cent females. The females are several times longer than the males.

The developmental periods for *Cerambycobius cyaniceps* have been worked out from data covering the period between July 12 and October 4. The pupal period in July is 10 days or less, in August is from

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8 to 11 days, and in September from 9 to 12 days. During August it was ascertained that the entire developmental period exceeds 26 days.

The larvæ of Cerambycobius are described in the breeding notes as white, transversely lineolate, with a row of prominent hairs around the middle of each segment. The pupæ are elongate brown, with a short, obtuse, erect ovipositor, and with the dorsum of the abdomen marked with two dark spots on each segment. The brown exuvium is easily recognized from the ovipositor. The pupæ may be easily distinguished from those of Microdontomerus after a little practice. (See figure of pupa, Pl. I, fig. 3.)

Secondary parasitism: On September 14 a female Cerambycobius was bred from a larva which was found feeding on a Catolaccus pupa in material collected August 28 at Calvert. Although numerous cases of parasitism of *Bracon mellitor* were found, only 11.5 per cent of this species were secondary parasites. It was found as a secondary parasite on Bracon as follows:

Beeville, Tex., July 12, 1 female.
Corpus Christi, Tex., July 10, 1 female.
Cuero, Tex., August 31, 1 female.
Mansfield, La., August 24, 2 females.
Trinity, Tex., August 9, 1 male, 1 female.
Victoria, Tex., September 1, 1 female.
Waco, Tex., August 28, 3 males, 10 females.
Waco, Tex., September 19, 1 male, 2 females.

In one case the attack of the Bracon is known to have been prior to spinning.

5. *Catolaccus incertus* Ashm. This species has been one of the most important species mentioned in the literature of the boll weevil. It was described as a primary parasite of *Anthonomus signatus* (Chittenden, 1893a). It was reared by F. H. Chittenden from *Apion decoloratum* Sm. breeding in *Meibomia paniculata* at Washington, D. C., from *Apion griseum* Sm. breeding in *Phaseolus perennis* at Washington, D. C., and from *Bruchus exiguus* (Chittenden, 1893b).

Two females were bred by the writer October 16, 1905, from *Anthonomus disjunctus* breeding in the heads of *Heterotheca subaxillaris* collected at Jacksonville, Tex. From *Anthonomus eugenii* breeding in peppers at San Antonio, Tex., F. C. Pratt bred 3 females on October 18, 1905. From *Anthonomus albopilosus* breeding in the seed of *Croton engelmanni* at Johnsons Bayou, La., the writer bred 2 females on September 6, 1906, and from the same weevil breeding in *Croton capitatus* at Leesville, La., the writer bred 1 female on September 29, and subsequently 3 females and 3 males.

Catolaccus incertus is very common in all parts of the State and is well established as a boll weevil parasite. (See Plate III, *E*.) It is a continuous breeder, attacking the weevil larvæ and pupæ, one individual for each host. The developmental period seems to be considerably shorter than in either of the species preceding. The data upon which the following figures are based cover the period from June 25 to October 28. During June and July the total developmental period is known to be over 11 or 12 days, during August it is over 14 days, and during September and October over 18 days. The pupal period in June and July is only 4 to 6 days, in August 6 to 7 days, in September 5 to 9 days, but in October 13 to 15 days.

The larvæ of Catolaccus were described in the notes as having short hairs in a row on each segment. The pupæ are white to yellow, the thorax turning black first as they approach maturity. The abdomen is very flat below and bent at an obtuse angle to the thorax. The head is very broad, and the eyes are pink. The exuvium is yellowish and resembles a little pointed cap. (See figure of pupa, Pl. I, fig. 2.)

6. *Sigalphus curculionis* Fitch. No corroboration has been recorded of the parasitism of the boll weevil by this species. This parasite is very commonly bred from the plum curculio (*Conotrachelus nenuphar* Hbst.). Chittenden also records it as a primary parasite of *Trichobaris trinotata* Say, which breeds in the stems of *Solanum rostratum* (Chittenden, 1902).

7. *Urosigalphus anthonomi* Cwfd. This parasite was again bred September 20 from material collected September 5 at Brownsville. The period in the cocoon was at least 9 days. The cocoon with weevil larva's head attached was half in a cotton seed in a boll. It was very much finer meshed than that of *Bracon mellitor* and easily broken. In addition to this species and (8) *Urosigalphus schwarzi* Cwfd., both bred from *Anthonomus grandis*, *Urosigalphus armatus* Ashm. has been bred from Balaninus, and another species (*Urosigalphus bruchi* Cwfd.) from *Bruchus prosopis* Lec. taken at Harlingen, Tex., in beans of *Prosopis glandulosa.* Hence it is very probable that the species of this genus are normally weevil parasites.

9, 10. *Bracon mellitor* Say. *Bracon dorsator* Say. *Bracon xanthostigma* Cress.

These are all forms of a single very variable species, of which the entirely red form holds the name *B. mellitor*, that with black sternum and metathorax the name *B. xanthostigma*, and that with the thorax almost entirely black and the vertex of the head also black, being also smaller in size, has been known as *B. dorsator*.

A peculiar record is furnished by F. H. Chittenden who reared this species from the strawberry leaf-roller *Ancylis* (*Phoxopteris*) *comptana* Fröl., from material collected at Cabin John, Md., July 9, 1899.

In a personal letter dated August 30, 1906, Dr. Wm. H. Ashmead writes: "*Bracon mellitor* Say is undoubtedly a most important parasite, widely distributed in the United States, and must affect very many different beetles, although usually rhynchophorous beetles."

The typical form has been bred from *Anthonomus grandis* at all times and in all places between June 15 and October 4. The form *xanthostigma* has only been bred from the boll weevil between September 16 and April 28, while *dorsator* was bred August 2, 1903, at Victoria; November 20, 1895, at Goliad, and December 17, 1895, at Beeville. *B. mellitor* was bred June 19, 1905, at Dallas by W. W. Yothers from *Anthonomus fulvus* Lec., which breeds in the buds of *Callirrhoe involucrata*, and on June 14 he bred *dorsator* from the same weevil. On September 20, 1905, F. C. Pratt bred male and female *dorsator* and female *mellitor* from *Desmoris scapalis* Lec., breeding in the flower heads of *Sideranthus rubiginosus* at Mexia, Tex.; on September 23 he bred the typical form from the same weevil collected at Calvert, Tex.; on September 29 both the typical form and *dorsator* from Mexia material; and on October 27 he again bred the typical form from Mexia material. On September 30, 1905, the writer bred *mellitor* and *xanthostigma* from *Anthonomus squamosus* Lec., breeding in the heads of *Grindelia squarrosa nuda* at Clarendon, Tex.; on October 2, 4 of the typical form and 1 *xanthostigma* were bred; on October 3, 3 typical, and finally on October 16 a *xanthostigma*, were bred. On October 18 and 23 *dorsator* was bred by F. C. Pratt from *Anthonomus eugenii* Cano, breeding in peppers at San Antonio, Tex. On September 6, 1906, J. D. Mitchell bred a typical form from *Anthonomus albopilosus* Dietz, breeding in seed of *Croton capitatus* at Victoria, Tex.

The data upon the life-cycle of *Bracon mellitor* cover the period from June 25 to November 15. The entire developmental period covers at least 21 days in June and 33 in October, but probably considerably more. The period within the cocoon has been limited to between 5 and 6 days in June, to 7 days in July, 6 to 11 days in August, 3 to 7 days in September, and 15 to 27 days in October. The minimum of 3 days in September is based upon an observation of the spinning of the cocoon and the time of maturity, and the record of 5 days in June was obtained in the same manner.

The larvæ of Bracon can be immediately separated by the absence of hairs and by the body being punctate instead of lineolate. The pupæ are yellowish, loosely constructed, with the appendages very fragile and inclosed in a stout one-meshed silken cocoon, which varies from pure white to golden yellow or dark brown. In several cases where particular note was made of the brown color of the cocoon hyperparasites were bred, but this was not a constant indication. The species varied greatly in size, depending upon the amount of food available. (See figures of larva and pupa, Pl. I, figs. 5, 6.)

No dark forms of this species were bred until September 10, 1906, except a single *B. dorsator* which was bred from Cuero material collected August 31. The rest were all bred from material collected at Brownsville, September 29; Dallas, October 2, 6, 10; and Waco, October 12. The record of all Bracon bred after October 10 is as follows:

October 10, *Bracon mellitor*, 3 males, 5 females.
11, Do. 1 male.
12, Do. 1 male.
13, Do. 1 female; *mellitor xanthostigma*, 2 females.
15, Do. 1 female.
18, *Bracon mellitor xanthostigma*, 3 females.
20, Do. 2 females.
22, *Bracon mellitor*, 3 females; *mellitor xanthostigma*, 2 females; *mellitor dorsator*, 2 males, 1 female.
24, *Bracon m. xanthostigma*, 1 female.
25, Do. 2 females; *m. dorsator*, 1 female.
31, Do. 2 females.
November 1, Do. 3 females; *m. dorsator*, 1 male.
5, Do. 1 female.
6, *Bracon mellitor dorsator*, 1 female.
14, *Bracon mellitor xanthostigma*, 1 female.

11. An undetermined braconid of the size of *Bracon mellitor*, but with the base of the abdomen black and belonging to a different subfamily, was bred September 17 from a yellow cocoon in a fallen square collected at Victoria, Tex., September 1. Unfortunately this was lost in the mails.

12. *Myiophasia ænea* Wied. This species is recorded as a parasite of *Balaninus nasicus* Say, *Chalcodermus* sp., *Conotrachelus juglandis* Lec., and *Sphenophorus parvulus* Gyll. (Coquillett, 1897), and also of *Ampeloglypter sesostris* Lec. (Aldrich, 1905). One specimen was bred July 6 by the writer from a larva of *Conotrachelus affinis* Boh. found in a hickory nut collected June 8 at Logansport, La. As parasites of the boll weevil from fallen squares collected at Many, La., August 23, 1 male was bred September 5 and 1 female September 8, while 1 failed to mature. From a hanging square collected at Waco, Tex., August 29, a puparium was obtained but the fly not bred. From a small boll collected at Victoria, Tex., July 12, a deformed fly was bred.

Parasitism by this species can always be positively proved if the puparium is found, as it is inside of the stretched skin of the weevil larva. The affected larva is of a tawny parchment color and shows the projections of the appendages of the fly puparium.

The developmental period is undoubtedly in excess of 28 days, as shown by the first record above.

13. Several attempts have been made to introduce *Pediculoides ventricosus* Newp. into Texas as a parasite of the boll weevil, but

with no success. Much has been written upon this mite by Professor Herrera and his staff.

14. There are, however, native mites, including *Tyroglyphus breviceps* Banks (Banks, 1906, p. 17), which in some cases are a considerable factor in the destruction of the immature weevils. At Calvert, Tex., in moist fallen squares collected September 13, 11 out of 18 cases of parasitism were mites. *T. breviceps* was described from Victoria.

15. *Hydnocera pubescens* Lec. This clerid was found to be predaceous in its larval stage upon the boll weevil and all of its parasites. The egg is probably inserted into the cell of the weevil, and the young predator immediately starts its attack, consuming whatever it finds in the way of insects, and finally spins a loosely meshed, single-layer, silken cocoon, and pupates therein. From data of material collected at Waco, Tex., August 28, an approximation of the developmental periods was obtained. The longest period from collection to spinning was 34 days, the period in the cocoon was 12 days, the adult being formed 3 days before leaving the cocoon. In order to prove the predaceous habit live weevil pupæ were furnished individual clerid larvæ, and in most cases were completely consumed. In several cases large larvæ were found in Bracon cocoons which were punctured with holes large enough only for the very smallest of the larvæ.

16. In a number of cases, material collected at Victoria, Dallas, and Brownsville gave evidence of a predaceous attack upon weevil stages by *Cathartus cassiæ* Reiche.

IV. THE SOURCES OF THE PARASITES.

In the preceding sections it has been pointed out that the parasites of *Anthonomus grandis* are also common to various other species of weevils. There is a more or less clearly defined theory in parasitology that the parasites of a particular genus or tribe are confined to the insects of a particular family or order. With this idea in mind a list of the known parasites of the Rhynchophora has been compiled, in order to show the characteristic groups and the possible sources of boll-weevil parasites.

PARASITES KNOWN TO ATTACK RHYNCHOPHORA.

Parasite.	Host.
Fungi.	
Aspergillus sp	*Anthonomus grandis* Boh.
Cordyceps sp	*Anthonomus grandis* Boh.
Empusa (*Entomophthora*) *sphærosperma*	*Phytonomus punctatus* Fab.
Entomophthora phytonomi	*Phytonomus punctatus* Fab.
Sporotrichum globuliferum	*Epicærus imbricatus* Say.

Parasite.	Host.
Acarina.	
Tarsonemidæ.	
Pediculoides ventricosus Newp	*Anthonomus eugenii* Cano.
	Anthonomus grandis Boh.
Tyroglyphidæ.	
Tyroglyphus breviceps Banks	*Anthonomus grandis* Boh.
(?)	*Anthonomus eugenii* Cano.
Diptera.	
Dexiidæ.	
Metadexia basalis G. T.	*Conotrachelus juglandis* Lec.
Tachinidæ.	
Myiophasia ænea Wied	*Ampeloglypter sesostris* Lec.
	Anthonomus grandis Boh.
	Balaninus nasicus Say.
	Chalcodermus æneus Boh.
	Conotrachelus affinis Boh.
	Conotrachelus juglandis Lec.
	Sphenophorus parvulus Gyll.
Myiophasia robusta Coq	*Sphenophorus robustus* Horn.
Hymenoptera.	
Proctotrypoidea.	
Platygasteridæ. Platygasterinæ.	
Trichacis rufipes Ashm	?*Balaninus nasicus* Say.
Chalcidoidea.	
Torymidæ. Monodontomerinæ.	
Microdontomerus anthonomi Cwfd	*Anthonomus grandis* Boh.
	Brachytarsus alternatus Say.
Eurytomidæ. Eurytomini.	
Eurytoma magdalidis Ashm	*Magdalis armicollis* Say.
Eurytoma tylodermatis Ashm	*Anthonomus disjunctus* Lec.
	Anthonomus grandis Boh.
	Anthonomus squamosus Lec.
	Apion segnipes.[a]
	Lixus musculus Say.
	Lixus scrobicollis Boh.
	Orthoris crotchii Lec.
	Tyloderma foveolatum Say.
Bruchophagus herreræ Ashm	*Anthonomus grandis* Boh.
Cleonymidæ. Cleonyminæ.	
Cheiropachys colon L	*Magdalis ænescens* Lec.
Encyrtidæ. Eupelminæ. Eupelmini.	
Cerambycobius cyaniceps Ashm	*Anthonomus grandis* Boh.
	Anthonomus albopilosus Dietz.
	Bruchus exiguus Horn.[a]
	Lixus musculus Say.
	Trichobaris texana Lec.
	Tyloderma foveolatum Say.[a]
Pteromalidæ. Pteromalinæ. Metaponini.	
Bruchobius laticollis Ashm	*Bruchus pisorum* L.
Pteromalidæ. Pteromalinæ. Rhaphitelini.	

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[a] On the authority of F. H. Chittenden.

Parasite.	Host.
Chalcidoidea—Continued.	
Dinotus sp.	*Magdalis æneseens* Lec.
Pteromalidæ. Pteromalinæ. Pteromalini.	
Catolaccus anthonomi Ashm.	*Anthonomus signatus* Say.
Catolaccus cœliodis Ashm.	*Acanthoscelis acephalus* Say.
Catolaccus incertus Ashm.	*Anthonomus æneolus* Dietz.
	Anthonomus eugenii Cano.
	Anthonomus albopilosus Dietz.
	Anthonomus disjunctus Lec.
	Anthonomus fulvus Lec.
	Anthonomus grandis Boh.
	Anthonomus nigrinus Boh.
	Anthonomus signatus Say.
	Apion decoloratum Sm.[a]
	Apion griseum Sm.[a]
	Auletes tenuipes Lec.
	Bruchus exiguus Horn.[a]
	Zygobaris xanthoxyli Pierce.
Neocatolaccus tylodermæ Ashm.	*Lixus parcus* Lec.
	Lixus musculus Say.
	Tyloderma foveolatum Say.
Pteromalidæ. Spalangiinæ.	
Cerocephala pityophthori Ashm.	*Pityophthorus consimilis* Lec.
Cerocephala scolytivora Ashm.	A scolytid.
Eulophidæ. Entedoninæ. Omphalini.	
Omphale livida Ashm.	*Ceutorhynchus rapæ* Gyll.
Eulophidæ. Entedoninæ. Entedonini.	
Asecodes albitarsis Ashm.	*Magdalis ænescens* Lec.
Entedon lithocolletidis Ashm.	*Anthonomus nigrinus* Boh.
Eulophidæ. Tetrastichinæ. Tetrastichini.	
Tetrastichus sp.	*Orthoris crotchii* Lec.
Mymaridæ. Mymarinæ. Anaphini (egg parasites).	
Anaphes conotracheli Girault	*Conotrachelus nenuphar* Hbst.
Ichneumonoidea.	
Ichneumonidæ. Ophioninæ. Porizonini.	
Porizon conotracheli Riley	*Conotrachelus nenuphar* Herbst.
Braconidæ. Blacinæ. Calyptini.	
Calyptus tibiator Cress.	*Anthonomus signatus* Say.
Braconidæ. Sigalphinæ.	
Sigalphus canadensis Prov.	*Anthonomus scutellatus* Gyll.
Sigalphus copturi Riley ms.	*Podapion gallicola* Riley.[b]
	Cylindrocopturus longulus Lec.[b]
	Conotrachelus posticatus Boh.

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[a] On the authority of F. H. Chittenden.

[b] Breed together.

Parasite.	Host.
Ichneumonoidea—Continued.	
Sigalphus curculionis Fitch	*Anthonomus grandis* Boh.
	Conotrachelus juglandis? in nuts.
	Conotrachelus nenuphar Hbst.
	Trichobaris trinotata Say.
Sigalphus sp	*Chalcodermus æneus* Boh.
Sigalphus zygobaridis Cwfd	*Zygobaris xanthoxyli* Pierce.
Urosigalphus anthonomi Cwfd	*Anthonomus grandis* Boh. (Texas).
Urosigalphus armatus Ashm	*Balaninus* spp., *Conotrachelus* spp.
Urosigalphus bruchi Cwfd	*Bruchus prosopis* Lec.
Urosigalphus schwarzi Cwfd	*Anthonomus grandis* Boh. (Guatemala).
Braconidæ. Cheloninæ.	
Phanerotoma tibialis Hald	*Anthonomus nigrinus* Boh.
Braconidæ. Agathidinæ. Microdini.	
Microdus simillimus Cress	*Lixus scrobicollis* Boh.
Braconidæ. Braconinæ. Braconini.	
Glyptomorpha lixi Ashm	*Lixus scrobicollis* Boh.
Glyptomorpha mavaritus Cress	*Lixus scrobicollis* Boh.
Glyptomorpha novitus Cress	*Lixus musculus* Say.
Glyptomorpha rugator Say	*Lixus concavus* Say.
	Lixus musculus Say.
Vipio belfragei Cress	*Lixus scrobicollis* Boh.
Melanobracon simplex Cress	*Dendroctonus piceæperda* Hopk.
Microbracon nuperus Cress	*Orthoris crotchii* Lec.
Bracon analcidis Ashm	*Tyloderma fragariæ* Riley.
Bracon anthonomi Ashm	*Anthonomus signatus* Say.
Bracon mellitor Say	*Anthonomus eugenii* Cano.
	Anthonomus albopilosus Dietz.
	Anthonomus fulvus Lec.
	Anthonomus grandis Boh.
	Anthonomus squamosus Lec.
	Desmoris scapalis Lec.
Bracon pissodis Ashm	*Pissodes strobi* Peck.
Bracon rhyssemati Ashm. ms	*Rhyssematus lineaticollis* Say.
Bracon smicronygis Ashm. ms	*Smicronyx tychoides* Lec.
Bracon sp	*Tomicus pini* Say.
Bracon sp	*Brachytarsus limbatus* Say.
Bracon sp	*Baris* sp.
Braconidæ. Rhogadinæ. Rhyssalini.	
Rhyssalus pityophthori Ashm	*Pityophthorus* sp.
Braconidæ. Spathiinæ. Spathiini.	
Spathius canadensis Ashm	*Dryocœtes autographus* Ratz.
	(?) *Magdalis olyra*.
	Phlœosinus graniger Chap.
	Tomicus sp.

BIOLOGIES OF THE WEEVILS CONTRIBUTING PARASITES.

It is of considerable importance in framing means of combating the boll weevil with parasites that the weevils usually found in the vicinity of cotton fields should be thoroughly known. In order that the conclusions in this regard may be more thoroughly understood, this subject must be introduced by a series of brief biologies of all the weevil species which have contributed parasites to the attack of the boll weevil.

CURCULIONIDÆ. APIONINÆ.

1. *Apion decoloratum* Sm. breeds in *Meibomia paniculata.* It is parasitized at Washington, D. C., by *Catolaccus incertus.*

2. *Apion griseum* Sm. breeds in *Phaseolus perennis,* and is parasitized by the same species as the preceding.

CURCULIONINÆ. CLEONINI.

3. *Lixus musculus* Say makes a gall in the stems of *Polygonum pennsylvanicum.* The larvæ and pupæ are found in these galls. The weevil and its host plant are typical of the fall, the plant being found in low moist ground, frequently in close proximity to cotton fields. The weevil is attacked by two of the important boll-weevil parasites.

4. *Lixus scrobicollis* Say dwells in the stems of *Ambrosia trifida* and *psilostachya,* two of the commonest roadside and waste-place weeds throughout the country in summer and fall. The entire stem is riddled by the weevil larvæ, which pupate in cells of frass at the end of their burrows. *Eurytoma tylodermatis* and other parasites not concerned in the discussion have been bred from this weevil.

ERIRHININI.

5. *Desmoris scapalis* Lec. breeds in the seed heads of *Sideranthus rubiginosus,* a summer weed, which is very abundant in some localities along roadsides and on prairies. The larvæ are expelled with the seed and enter the ground for pupation, maturing in the following spring. This species is parasitized by *Bracon mellitor,* which has a much more rapid development than its host. (See Pl. III, *B, D, F, G.*)

ANTHONOMINI.

6. *Anthonomus* (*Anthonomorphus*) *fulvus* Lec. breeds in the buds of *Callirrhoe involucrata,* an early spring mallow, which is common in May and June on moist meadows. The larvæ feed upon the floral column of the bud or the imperfectly opened flower and pupate in a cell of excreta in the capsule or fallen corolla. *Bracon mellitor* and *Catolaccus incertus* have been bred from it. (See Pl. II.)

7. *Anthonomus signatus* Say, the strawberry weevil, breeds in a number of rosaceous plants, such as strawberry, blackberry, raspberry, and wild rose, as also in red-bud. It is an early spring weevil, ovipositing in the buds, which soon drop to the ground, where the larva transforms to the pupa stage. It is parasitized by *Catolaccus incertus.*

8. *Anthonomus nigrinus* Say is an eastern weevil which breeds in the buds of *Solanum carolinense* and various other solanaceous plants, occurring principally in the spring and early summer, but not confined to one generation. It oviposits in the buds, causing them to fall. The larva makes its cell in the center of the bud through the pistil and all of the stamens and pupates in this cell. It is a host of *Catolaccus incertus.*

9. *Anthonomus albopilosus* Dietz is a fall species which breeds in the seed of *Croton capitatus* and *C. engelmanni,* weeds which are very abundant in pastures. The larvæ eat out one seed and then enter a second and form their pupal cell in this. The weevil serves as a host to *Cerambycobius cyaniceps, Catolaccus incertus,* and *Bracon mellitor.*

10. *Anthonomus æneolus* Dietz is a spring species which breeds in the buds of *Solanum torreyi, S. rostratum,* and *S. eleagnifolium.* The larvæ feed within one or two anthers, in the latter case forming a cell which cements the two together. In many cases the flower does not fall, and is able to fruit. The weevil is a host of *Catolaccus incertus.*

11. *Anthonomus eugenii* Cano (*æneotinctus* Champ.), the pepper weevil, is a recent introduction from Mexico. It is a fall species, which breeds in the interior of the cultivated peppers. (See Plate III; *A, C.*) It is a host to *Catolaccus incertus, Bracon mellitor,* and *Pediculoides ventricosus,* as determined by Professor Herrera. *Anthonomus mexicanus* Boh., another pepper weevil, is very likely identical.

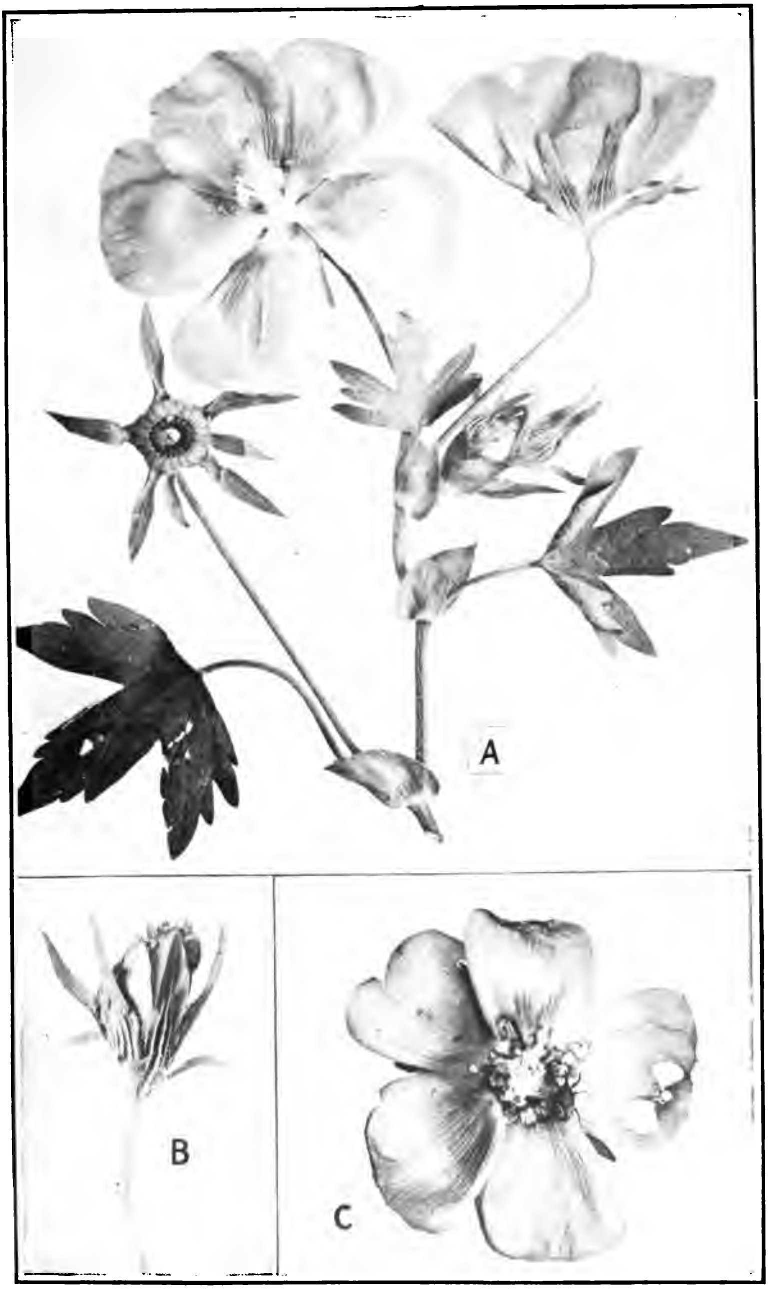
12. *Anthonomus squamosus* Lec. breeds in the heads of *Grindelia squarrosa,* a fall plains plant, which is very abundant in semiarid Texas. The weevil larva makes a cell among the seed, which is formed of the hardened gum of the flower and excreta. It has probably only one generation. It is very highly parasitized and principally by *Bracon mellitor* and *Eurytoma tylodermatis.*

13. *Anthonomus disjunctus* Lec. breeds in the heads of *Heterotheca subaxillaris,* a fall plant, which is very abundant along roads, waste places, and on meadows. The weevil larva makes a small cell, formed of the hardened gum and excreta of the weevil, among the seed. There is but one generation. *Eurytoma tylodermatis* and *Catolaccus incertus* have both been bred from this weevil.

CRYPTORHYNCHINI.

14. *Conotrachelus affinis* Boh., the hickory nut weevil, has been found to be the host of *Myiophasia ænea.* It is an early summer weevil. Pupation is in the ground.

15. *Conotrachelus nenuphar* Herbst, the plum and peach curculio, breeds in the fleshy part of the fruit and pupates in the ground. It is the host of *Sigalphus curculionis,* which has once been bred from *Anthonomus grandis.*



THE PURPLE MALLOW (CALLIRHOE INVOLUCRATA), A FOOD PLANT OF TWO WEEVILS RELATED TO THE BOLL WEEVIL.

Fig. A.—The buds and flowers, which are subject to attack by *Anthonomus fulvus*, and the capsule, subject to attack of *Macrorhoptus estriatus*. Fig. B.—Bud infested by *Anthonomus fulvus*. Fig. C.—Flower injured by adult weevil of *Anthonomus fulvus*. (Original.)

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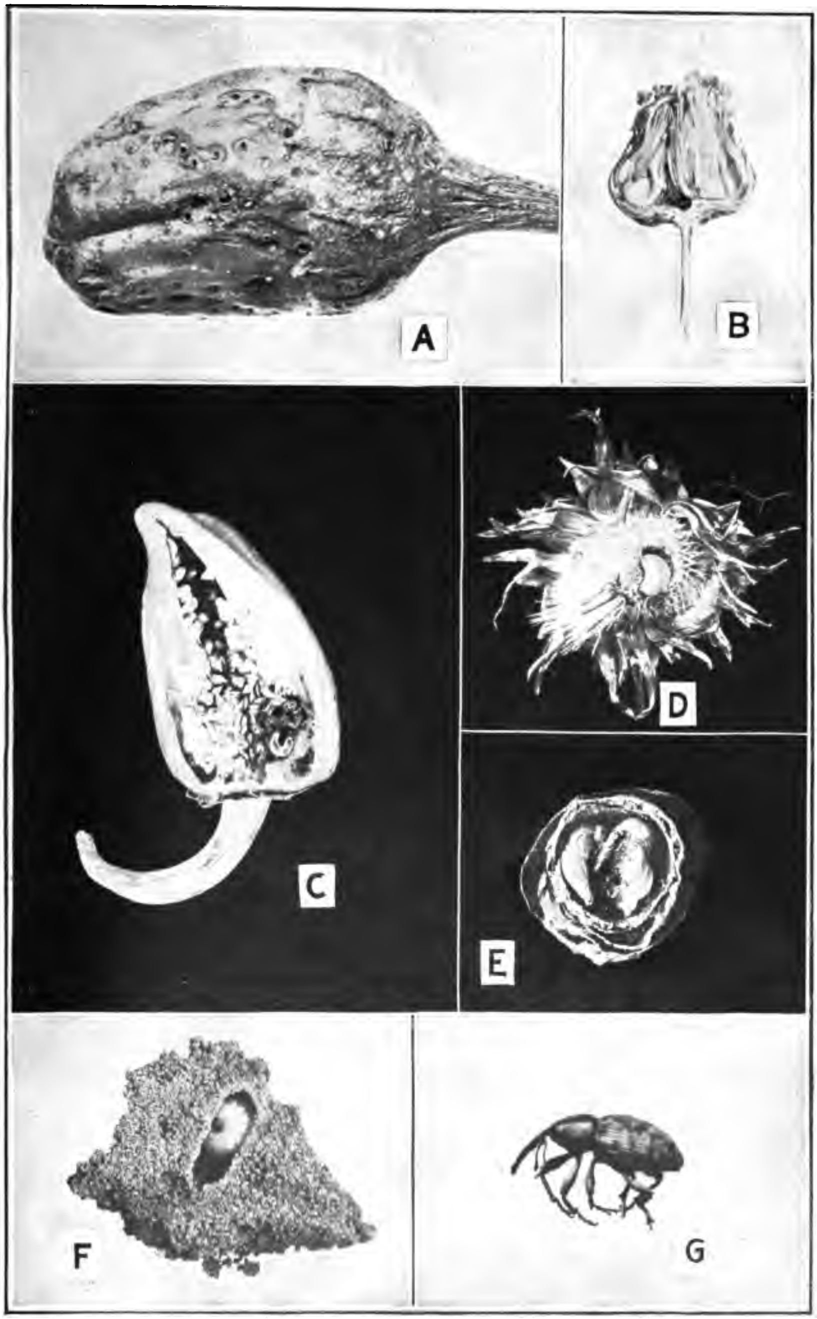

BIOLOGIES OF WEEVILS.

Fig. A.—Pepper, showing egg punctures of *Anthonomus eugenii*. Fig. B.—Head of *Sideranthus rubiginosus*, showing cell of *Desmoris scapalis*. Fig. C.—Pepper, showing larva of *Anthonomus eugenii* in situ. Fig. D.—Head of *Sideranthus rubiginosus*, with larva of *Desmoris scapalis* in its cell. Fig. E.—Section of cotton square, showing pupa of *Anthonomus grandis* and pupa of primary parasite *Catolaccus incertus*. Fig F.—Earthen cell of larva of *Desmoris scapalis*. Fig. G.—*Desmoris scapalis*, adult weevil. (Original.)

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16. *Chalcodermus æneus* Boh. is the cowpea-pod weevil, although it has once been bred from a cotton square. It is recorded as a host of *Myiophasia ænea*.

17. *Tyloderma foveolatum* Say breeds in the stems of *Onagra biennis*, an early summer evening primrose. Pupation takes place in the larval burrow. It is parasitized by *Eurytoma tylodermatis* and *Cerambycobius cyaniceps*.

CEUTORHYNCHINI.

18. *Auletes tenuipes* Lec. This species was found to breed in the buds of *Galpinsia hartwegi* at Dallas in the spring. The larvæ feed within a single anther in the bud, leaving it when the flower opens and entering the ground for pupation. The entire life cycle does not exceed 25 days, of which 11 days only is spent in the bud. *Catolaccus incertus* has been bred as a parasite.

BARINI.

19. *Orthoris crotchii* Lec. is a very abundant fall weevil in western Texas, breeding in the seed pods of *Mentzelia nuda*, a plains plant. Pupation is in a cell formed within several seeds. The species is highly parasitized by several species, the least of which, however, is *Eurytoma tylodermatis*.

20. *Trichobaris texana* Lec. is a stalk weevil, breeding in the stems of *Solanum rostratum*, a plant common in waste places in the summer and fall. The weevil cells are not more than an inch apart throughout the stem. *Cerambycobius cyaniceps* has been bred as a parasite.

21. *Trichobaris trinotata* Say, the potato stalk weevil, is another host of *Sigalphus curculionis*.

22. *Ampeloglypter sesostris* Lec. is a grapevine weevil, and a host of *Myiophasia ænea*. It is not recorded from Texas.

23. *Zygobaris xanthoxyli* Pierce. This new species breeds in the berries of Xanthoxylum at Runge and Beeville, Tex., in the spring. The larvæ feed in the interior of the seed until the seed is thrown to the ground. They then enter the soil and pupate in a tiny earthen cell, being in the ground about a month. *Catolaccus incertus* has been bred as a parasite.

ANTHRIBIDÆ.

24. *Brachytarsus alternatus* Say breeds in the stems of *Sideranthus rubiginosus*. It is a constant breeder, entirely riddling the stems. Microdontomerus has been bred from it.

BRUCHIDÆ.

Although not considered Rhynchophora by American writers, it is very probable that the Bruchidæ are a connecting link between the Anthribidæ and Chrysomelidæ.

25. *Bruchus exiguus* Horn breeds in the seed pods of *Amorpha fruticosa* in the fall. It is a host of *Cerambycobius cyaniceps* and *Catolaccus incertus*.

It is noticeable from the foregoing that *Bracon mellitor* attacks bud, flower, pod, and seed weevils; *Catolaccus incertus* attacks bud, pod, and seed weevils; *Cerambycobius cyaniceps* attacks bud, pod, and seed, but mainly stem weevils; *Eurytoma tylodermatis* attacks bud, flower, pod, and stem weevils; *Microdontomerus anthonomi* attacks bud, capsule, and stem weevils; *Myiophasia ænea* attacks bud, fruit, pod, nut, and stem weevils, and *Sigalphus curculionis* attacks bud, fruit, pod, and stem weevils. Such general habits indicate a generalization of habit in the species concerned and give promise of the possibility of more extensive adaptation to the boll weevil as a host.

ROTATION OF HOSTS.

The most important item in the solution of the parasite question is probably concerned with the treatment of the other hosts. It is found that the parasites which now attack the weevil are naturally parasitic on weevils of short season and few generations, and the most feasible proposition is that of forcing them to attack the boll weevil only.

Two lines of action are suggested as possible and practicable. The first is, that such plants as the Crotons, hosts of *Anthonomus albopilosus*, might be planted in abundance in the pastures because they make good feed and are easily destroyed, and that thus the weevils and their parasites would increase in great numbers and the latter might perhaps attack the boll weevil.

The counter proposal is that the timely elimination of the summer series of host plants would cut off the possibility of finding any host but the boll weevil, which would be in abundance. The cutting of the weeds around the fields could not result disadvantageously, as there are numerous pests harbored by these same weeds. At present the information as to the rotation of hosts is incomplete, and it is therefore necessary to go very fully into this question as well as to test both methods which have been suggested.

The known hosts of *Bracon mellitor* would insure it an uninterrupted rotation if they all occurred in a given locality. They do not, so there are still other unfound hosts of this species. The season of its hosts as far as known are as follows:

Anthonomus fulvus breeds from May 3 to July 12.
Desmoris scapalis breeds from July 25 to September 22.
Anthonomus squamosus breeds from August 11 to September 19.
Anthonomus albopilosus breeds from August 26 to September 29.
Anthonomus eugenii breeds from October 6 to October 31.

Important gaps exist in the host rotation of *Catolaccus incertus*. Its hosts breed as follows:

Anthonomus signatus breeds from April 11 to June 12.
Anthonomus fulvus breeds from May 3 to July 12.
Auletes tenuipes breeds from May 9 to May 25.
Zygobaris xanthoxyli breeds from May 11 to June 29.
Anthonomus æneolus breeds from May 17 to July 12.
Anthonomus nigrinus breeds from June 30 to July 18.
Anthonomus albopilosus breeds from August 26 to September 29.
Anthonomus eugenii breeds from October 6 to October 31.
Anthonomus disjunctus was found breeding October 11 to 14.

The known habits of the hosts of *Cerambycobius cyaniceps* are as follows:

Tyloderma foveolatum breeds from June 22 to September 23.
Trichobaris texana breeds from June 26 to October 11.
Lixus musculus breeds from August 11 to September 19.
Anthonomus albopilosus breeds from August 26 to September 29.

The following data comprise all that is known of the hosts of *Eurytoma tylodermatis:*

Tyloderma foveolatum breeds from June 22 to September 23.
Lixus scrobicollis breeds from July 12 to April 17 (following year).
Anthonomus squamosus breeds from August 11 to September 19.
Orthoris crotchii breeds from August 11 to September 19.
Lixus musculus breeds from August 11 to September 19.
Anthonomus disjunctus was found breeding October 11 to 14.

In the field at Dallas upon which release experiments were conducted, and in a series of five fields in various directions from Waco, it was found that the various species of parasites were exceedingly localized, indicating that the parasites were derived from the immediate vicinity.

On the Dallas field, by reference to the tables given in Section II, it will be noticed that Plat B with one small exception was the only plat in which Catolaccus was found; that Plat B was the only one from which Cerambycobius was bred; that Eurytoma was not found in Plat C, but was predominant on Plat E; and, finally, that Bracon was well distributed.

At Waco on all five fields *Bracon mellitor* was present in the proportion of 20 to 50 per cent. On the prairie land field, surrounded only by Ambrosia, Helianthus, and Xanthium, 41.6 per cent of the parasites were *Eurytoma tylodermatis*. On the other fields, which were on the bottoms, only one Eurytoma was taken to a field. *Catolaccus incertus* was present on the prairie land field and one bottom land field. Cerambycobius was present in all the bottom lands and very numerous, 58.3 per cent, in a field which had considerable *Solanum rostratum* about it; it was entirely absent on the prairie. The commonest plants on the bottoms were *Heterotheca subaxillaris*, *Croton* spp., *Solanum* spp., and Xanthium.

V. Conclusions and Prospects.

In conclusion the writer would say that there are a number of very important points obtained which indicate a possible natural control of the boll weevil. The actual combinations of conditions which bring about the instances of high parasitism can not be understood. It is very evident that the elements in the combination are relative moisture and light, plant response to weevil injury, abundance of other species of weevils in the immediate vicinity, and, finally, the ability for rapid adjustment to new host relations possessed by the local parasites.

Very high parasitism has been found, and it may therefore be expected again, perhaps locally, perhaps regionally. It may not necessarily be expected two years in succession at the same place, for a change in cultivation, an eradication of certain surrounding plants, or various other conditions might destroy the advantages previously gained. On the other hand, these same agencies in another locality might attain the opposite result.

Release of parasites in the open field on a small scale has been found to increase the rate of parasitization. This will be tried on a more extensive and better planned outline another year.

The abundance of hosts which have parasites in common with the weevil and the fact that parasitization takes place in the first generation give promise that the weevil's advance may be constantly disputed by the parasites.

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INDEX.

Page.
Acanthoscelis acephalus, host of *Catolaccus cœliodis* 43
Ambrosia, occurrence with reference to that of *Eurytoma tylodermatis* 49
  psilostachya, food plant of *Lixus scrobicollis* 35, 45
  trifida, food plant of *Lixus scrobicollis* 25, 35, 45
Amorpha fruticosa, food plant of *Bruchus exiguus* 48
Ampeloglypter sesostris, biological notes 47
  host of *Myiophasia ænea* 40, 42
Anaphes conotracheli, parasite of *Conotrachelus nenuphar* 43
Ancylis comptana, host of *Bracon mellitor* 38
Anthonomorphus fulvus=*Anthonomus fulvus* 45
Anthonomus æneolus, biological notes 46
  breeding period 49
  host of *Catolaccus incertus* 43
 æneotinctus=*A. eugenii* 46
 albopilosus, biological notes 46
  breeding period 48, 49
  host of *Bracon mellitor* 39, 44
   Catolaccus incertus 37, 43
   Cerambycobius cyaniceps 36, 42
  in *Croton capitatus* 37, 39
   engelmanni 36–37
   Crotons 4–5, 48
 disjunctus, biological notes 46
  breeding period 49
  host of *Catolaccus incertus* 37, 43
   Eurytoma tylodermatis 34, 42
  in *Heterotheca subaxillaris* 34, 37
 eugenii, *A. æneotinctus* a synonym 46
  biological notes 46
  breeding period 48, 49
  host of *Bracon mellitor* 44
   form *dorsator* 39
   Catolaccus incertus 37, 43
   Pediculoides ventricosus 42
   Tyroglyphus breviceps 42
  in peppers 37, 39
 fulvus, biological notes 45
  breeding period 48, 49
  host of *Bracon mellitor* 39, 44
   form *dorsator* 39
   Catolaccus incertus 43
  in *Callirrhoe involucrata* 39
 grandis (*see also* Boll weevil).

Page.

Anthonomus grandis, host of *Aspergillus* sp., 41
        Braconid, 29, 40
        Bracon mellitor, 44
                and its forms, 39
        Bruchophagus herreræ, 42
        Catolaccus incertus, 43
        Cerambycobius cyaniceps, 42
        Cordyceps sp, 41
        Eurytoma tylodermatis, 42
        Microdontomerus anthonomi, 28, 42
        Myiophasia ænea, 42
        Pediculoides ventricosus, 42
        Sigalphus curculionis, 44, 46
        Tyroglyphus breviceps, 42
        Urosigalphus anthonomi, 38, 44
                schwarzi, 38, 44
    possibly a host of *Catolaccus anthonomi*, 31
  mexicanus probably = *A. eugenii*, 46
  nigrinus, bibliographic reference, 51
    biological notes, 46
    breeding period, 49
    host of *Catolaccus incertus*, 43
        Entedon lithocolletidis, 43
        Phanerotoma tibialis, 44
  scutellatus, host of *Sigalphus canadensis*, 43
  signatus, bibliographic reference, 51
    biological notes, 45
    breeding period, 49
    host of *Bracon anthonomi*, 44
        Calyptus tibiator, 43
        Catolaccus anthonomi, 31, 43
                incertus, 37, 43
  squamosus, biological notes, 46
    breeding period, 48, 49
    host of *Bracon mellitor*, 39, 44
                form *xanthostigma*, 39
        Eurytoma tylodermatis, 34, 42
    in *Grindelia squarrosa nuda*, 34, 39
Ant. (See *Solenopsis geminata*.)
Apion decoloratum, biological notes, 45
    host of *Catolaccus incertus*, 37, 43
    in *Meibomia paniculata*, 37
  griseum, biological notes, 45
    host of *Catolaccus incertus*, 37, 43
    in *Phaseolus perennis*, 37
  segnipes, host of *Eurytoma tylodermatis*, 42
Asecodes albitarsis, parasite of *Magdalis ænescens*, 43
Aspergillus sp., fungous enemy of boll weevil (*Anthonomus grandis*), 11, 28, 41
Auletes tenuipes, biological notes, 47
    breeding period, 49
    host of *Catolaccus incertus*, 43
Balaninus, host of *Urosigalphus armatus*, 38
  nasicus, host of *Myiophasia ænea*, 40, 42

Page.

- ***Balaninus nasicus*** (?), host of *Trichacis rufipes* 42
  - spp., hosts of *Urosigalphus armatus* 44
- ***Baris*** sp., host of *Bracon* sp 44
- **Birds**, factor in control of boll weevil 3
- **Blackberry**, food plant of *Anthonomus signatus* 45
- **Bolls**, fallen, percentage of parasitism of boll weevil 14, 15, 16, 21
  - hanging, percentage of parasitism of boll weevil 14, 15, 16, 21
  - percentage of parasitism of boll weevil in 1905 13
- **Boll** weevil (see also *Anthonomus grandis*).
  - checks on increase 3
  - chronology and parasitism 21
  - control by wide spacing 5, 22
  - factors in control 3
  - hyperparasites, list 28
  - parasites. (*See* Parasites of boll weevil.)
  - predaceous enemies, list 28
  - primary parasites, list 27–28
  - stages in fallen forms, parasitism 22
    - hanging forms, parasitism 22
  - status and parasitism 19–20
- ***Brachytarsus alternatus***, biological notes 47
  - host of *Microdontomerus anthonomi* 32, 42
  - in *Sideranthus rubiginosus* 32
  - *limbatus*, host of *Bracon* sp 44
- ***Bracon analcidis***, parasite of *Tyloderma fragariæ* 44
  - *anthonomi*, parasite of *Anthonomus signatus* 44
  - *dorsator* = form of *B. mellitor* 11, 29, 38
    - occurrence 29
    - parasite of boll weevil 11, 28
  - general occurrence 49
  - *mellitor*, accidental host of *Cerambycobius cyaniceps*, *Eurytoma tylodermatis*, and *Microdontomerus anthonomi* 28, 33–34, 34–35, 37
    - artificial propagation as parasite of boll weevil 22
    - biological notes 38–40
    - *Bracon dorsator* a synonym 11, 29
      - *xanthostigma* a synonym 29
    - center of activity as boll weevil parasite 9
    - general occurrence 49
    - geographical and seasonal distribution 31–32
    - hosts, list 44
    - occurrence 29, 30
    - parasite of *Anthonomus albopilosus* 46
      - *eugenii* 46
      - *fulvus* 45
      - *squamosus* 46
      - boll weevil 11, 28
      - bud, flower, pod, and seed weevils 48
      - *Desmoris scapalis* 45
    - release experiments 25, 26
    - rotation of hosts 48
  - *pissodis*, parasite of *Pissodes strobi* 44
  - *rhyssemati*, parasite of *Rhyssematus lineaticollis* 44
  - *smicronygis*, parasite of *Smicronyx tychoides* 44

Page.

- *Bracon* sp., parasite of *Baris* sp 44
  - *Brachytarsus limbatus* 44
  - *Tomicus pini* 44
- *xanthostigma* = *B. mellitor* 29, 38
  - occurrence 29
- Braconid parasite of boll weevil 29, 40
- Breeding records of parasites of boll weevil, 1906 13–22
  - work on parasites of boll weevil 11, 27–41
- Bruchidæ, probably a connecting link between Anthribidæ and Chrysomelidæ 47
- *Bruchobius laticollis*, parasite of *Bruchus pisorum* 42
- *Bruchophagus herreræ*, occurrence 29
  - parasite of boll weevil (*Anthonomus grandis*) 11, 27, 36, 42
  - new, bibliographic reference 51
- *Bruchus exiguus*, biological notes 48
  - host of *Catolaccus incertus* 37, 43
    - *Cerambycobius cyaniceps* 36, 42
  - *pisorum*, host of *Bruchobius laticollis* 42
  - *prosopis*, host of *Urosigalphus bruchi* 38, 44
    - in *Prosopis glandulosa* 38
- *Callirrhoe involucrata*, food plant of *Anthonomus fulvus* 39, 45
- *Calyptus tibiator*, parasite of *Anthonomus signatus* 43
- *Cathartus cassiæ*, enemy of boll weevil 28–41
  - occurrence 30
- *Catolaccus anthonomi*, occurrence 30–31
  - parasite of *Anthonomus signatus* 31, 43
  - possible primary parasite of boll weevil 28
  - *cœliodis*, parasite of *Acanthoscelis acephalus* 43
  - *incertus*, biological notes 37–38
    - center of activity as boll-weevil parasite 9
    - geographical and seasonal distribution 31–32
    - hosts, list 43
    - localization 49
    - occurrence 29, 30
    - parasite of *Anthonomus albopilosus* 46
      - *disjunctus* 46
      - *eugenii* 46
      - *fulvus* 45
      - *nigrinus* 46
      - *signatus* 45
      - *Apion decoloratum* 45
        - *griseum* 45
      - *Auletes tenuipes* 47
      - boll weevil 11, 27
      - *Bruchus exiguus* 48
      - bud, pod, and seed weevils 48
      - *Zygobaris xanthoxyli* 47
    - release experiments 25, 26
    - rotation of hosts 49
  - localization 49
- *Cerambycobius cyaniceps*, accidental parasite of *Bracon mellitor* 28, 34, 37
  - biological notes 36–37
  - center of activity as boll weevil parasite 9
  - geographical and seasonal distribution 31–32

Page.

- *Cerambycobius cyaniceps*, hosts, list 42
  - hyperparasite of boll weevil 28, 34, 37
  - occurrence 29, 30
  - parasite of *Anthonomus albopilosus* 46
    - boll weevil 11, 27
    - *Bruchus exiguus* 48
    - bud, pod, seed, and stem weevils 48
    - *Lixus musculus* 25
    - *Trichobaris texana* 47
      - *trinotata* 25
    - *Tyloderma foveolatum* 47
  - release experiments 25, 27
  - rotation of hosts 49
  - localization 49
- *Cerocephala pityophthori*, parasite of *Pityophthorus consimilis* 43
  - *scolytivora*, parasite of scolytid 43
- *Ceutorhynchus rapæ*, host of *Omphale livida* 43
- *Chalcodermus æneus*, biological notes 47
  - host of *Myiophasia ænea* 42
    - *Sigalphus* sp 44
  - sp., host of *Myiophasia ænea* 40
- *Cheiropachys colon*, parasite of *Magdalis ænescens* 42
- Chronology of boll weevil as related to parasitism 21
- *Conotrachelus affinis*, biological notes 46
  - host of *Myiophasia ænea* 40, 42
  - in hickory nut 40
  - *juglandis*, host of *Metadexia basalis* 42
    - *Myophasia ænea* 40, 42
  - *juglandis* (?), host of *Sigalphus curculionis* 44
  - *nenuphar*, biological notes 46
    - host of *Anaphes conotracheli* 43
      - *Porizon conotracheli* 43
      - *Sigalphus curculionis* 38, 44
  - *posticatus*, host of *Sigalphus copturi* 43
  - spp., hosts of *Urosigalphus armatus* 44
- *Cordyceps* sp., parasite of boll weevil (*Anthonomus grandis*) 10, 28, 41
- Cotton, food plant of *Chalcodermus æneus* 47
  - forms, fallen, parasitism of boll weevil 22
    - hanging, parasitism of boll weevil 22
  - varieties favorable to boll weevil control 5, 22
  - wide spacing for control of boll weevil 5, 22
- Cowpea-pod weevil. (See *Chalcodermus æneus*.)
- *Croton capitatus*, food plant of *Anthonomus albopilosus* 37, 39, 46
  - *engelmanni*, food plant of *Anthonomus albopilosus* 36, 37, 46
  - spp., food plants of *Anthonomus albopilosus* 4–5, 48
    - occurrence with reference to that of Cerambycobius 49
- *Cylindrocopturus longulus*, host of *Sigalphus copturi* 43
- *Dendroctonus piceæperda*, host of *Melanobracon simplex* 44
- *Desmoris scapalis*, biological notes 45
  - breeding period 48
  - host of *Bracon mellitor* 39, 44
    - form *dorsator* 39
  - in *Sideranthus rubiginosus* 39

Page.
Determinate growth, factor in control of boll weevil.......... 3
Dinotus sp., parasite of *Magdalis ænescens*.......... 43
Dryness and sunlight favorable to parasitism of boll weevil.......... 22
Dryocœtes autographus, host of *Spathius canadensis*.......... 44
Empusa (*Entomophthora*) *sphærosperma*, fungous disease of *Phytonomus punctatus*.......... 41
Entedon lithocolletidis, parasite of *Anthonomus nigrinus*.......... 43
Entomophthora phytonomi, fungous enemy of *Phytonomus punctatus*.......... 41
sphærosperma. (See *Empusa* [*Entomophthora*] *sphærosperma*.)
Epicærus imbricatus, host of *Sporotrichum globuliferum*.......... 41
Eupelmus cyaniceps=*Cerambycobius cyaniceps*.......... 11
Eurytoma, localization.......... 49
magdalidis, parasite of *Magdalis armicollis*.......... 42
species parasitic on boll weevil.......... 11
tylodermatis, accidental parasite of *Bracon mellitor*.......... 28, 34, 35–36
biological notes.......... 34
center of activity as boll weevil parasite.......... 9
geographical and seasonal distribution.......... 31–32
hosts, list.......... 42
hyperparasite of boll weevil.......... 28, 34, 35–36
localization.......... 49
occurrence.......... 29, 30
parasite of *Anthonomus disjunctus*.......... 46
squamosus.......... 46
Apion segnipes.......... 42
boll weevil.......... 11, 27
bud, flower, pod, and stem weevils.......... 48
Lixus scrobicollis.......... 25, 26, 27, 45
Orthoris crotchii.......... 47
Tyloderma foveolatum.......... 47
rotation of hosts.......... 49
Examination work on parasites of boll weevil.......... 11–22
Formica fusca subpolita perpilosa, enemy of boll weevil.......... 28
Fungous enemies of boll weevil. (See *Aspergillus* sp. and *Cordyceps* sp.)
Epicærus imbricatus. (See *Sporotrichum globuliferum*.)
Phytonomus punctatus. (See *Empusa* [*Entomophthora*] *sphærosperma* and *Entomophthora phytonomi*.)
Galpinsia hartwegi, food plant of *Auletes tenuipes*.......... 47
Geographical considerations governing parasitism of boll weevil.......... 18–19
Glyptomorpha lixi, parasite of *Lixus scrobicollis*.......... 44
mavaritus, parasite of *Lixus scrobicollis*.......... 44
novitus, parasite of *Lixus musculus*.......... 44
rugator, parasite of *Lixus concavus* and *L. musculus*.......... 44
Grapevine, food plant of *Ampeloglypter sesostris*.......... 47
Grindelia squarrosa, food plant of *Anthonomus squamosus*.......... 46
nuda, food plant of *Anthonomus squamosus*.......... 34–39
Heat and dryness, factor in control of boll weevil.......... 3
Helianthus, occurrence with reference to that of *Eurytoma tylodermatis*.......... 49
Heterotheca subaxillaris, food plant of *Anthonomus disjunctus*.......... 34, 37, 46
occurrence with reference to that of Cerambycobius.......... 49
Hibernation of boll weevil parasites in bolls.......... 12
Hickory, food plant of *Conotrachelus affinis*.......... 40
nut weevil. (See *Conotrachelus affinis*.)

	Page.
Hydnocera pubescens, biological notes	41
enemy of boll weevil	28
occurrence	30
Insanthonomus grandis. (See *Anthonomus grandis* and Boll weevil.)	
Leaf-worm, factor in control of boll weevil	3
Lixus concavus, host of *Glyptomorpha rugator*	44
musculus, biological notes	45
breeding period	49
host of *Cerambycobius cyaniceps*	25, 36, 42
Eurytoma tylodermatis	34, 42
Glyptomorpha novitus	44
rugator	44
Neocatolaccus tylodermæ	43
in *Polygonum pennsylvanicum*	25, 34, 36
parcus, host of *Neocatolaccus tylodermæ*	43
scrobicollis, biological notes	45
breeding period	49
host of *Eurytoma tylodermatis*	25, 34, 35, 42
Glyptomorpha lixi	44
mavaritus	44
Microdus simillimus	44
Vipio belfragei	44
in *Ambrosia trifida*	25, 34
psilostachya	34–35
Magdalis ænescens, host of *Asecodes albitarsis*	43
Cheiropachys colon	42
Dinotus sp	43
armicollis, host of *Eurytoma magdalidis*	42
olyra (?), host of *Spathius canadensis*	44
Meibomia paniculata, food plant of *Apion decoloratum*	37, 45
Melanobracon simplex, parasite of *Dendroctonus piceæperda*	44
Mentzelia nuda, food plant of *Orthoris crotchii*	34, 47
Metadexia basalis, parasite of *Conotrachelus juglandis*	42
Microbracon nuperus, parasite of *Orthoris crotchii*	44
Microdontomerus anthonomi, accidental parasite of *Bracon mellitor*	28, 33–34
biological notes	32–34
hyperparasite of boll weevil	28, 33–34
occurrence	28
parasite of boll weevil (*Anthonomus grandis*)	27, 42
Brachytarsus alternatus	42
bud, capsule, and stem weevils	48
parasite of *Brachytarsus alternatus*	47
Microdus simillimus, parasite of *Lixus scrobicollis*	44
Myiophasia ænea, biological notes	40
hosts, list	42
occurrence	30
parasite of *Ampeloglypter sesostris*	47
boll weevil	28
bud, fruit, pod, nut, and stem weevils	48
Chalcodermus æneus	47
Conotrachelus affinis	46
robusta, parasite of *Sphenophorus robustus*	42
Neocatolaccus tylodermæ, hosts, list	43

Page.

Omphale livida, parasite of *Ceutorhynchus rapæ* 43
Onagra biennis, food plant of *Tyloderma foveolatum* 34, 36, 47
Orthoris crotchii, biological notes 47
  breeding period 49
  host of *Eurytoma tylodermatis* 34–42
    Microbracon nuperus 44
    Tetrastichus sp. 43
  in *Mentzelia nuda* 34
Parasites, factor in control of boll weevil 3–5
  known to attack Rhynchophora 41–44
  of boll weevil, artificial propagation 4, 22
    bibliography 51–52
    biological notes 32–41
    biologies of weevils contributing them 44–48
    breeding records of 1906 13–22
    breeding work 11, 27–41
    conclusions 50
      from work of 1906 21–22
    elimination of natural hosts [other weevils] 4–5
    examination work 11–22
    field work 24–27
    geographical and seasonal distribution 31–32
    hibernation in bolls 12
    history 10–11
    intensive centers 9
    occurrence of species 28–31
    percentage in bolls versus squares in 1905 13
    propagation work 11, 22–27
    prospects 50
    records prior to 1906 12–13
    release experiments 24–27
    rotation of hosts 48–49
    schemes for increasing their work 48
    source work 11, 41–50
    transfer or artificial propagation, apparatus and difficulties 22–24
    work of 1906, conclusions 11, 50
Parasitism and status of boll weevil 19–20
  of boll weevil and chronology 21
    by months, 1906 14
    field conditions 17–18
    geographical considerations 18–19
    in fallen bolls 14, 15, 16, 21
      forms 22
        in shade versus sun 17, 18, 22
      squares 14, 15, 16, 21
     forms in prairie versus woodland 17, 18, 22
     hanging bolls 14, 15, 16, 21
      forms 22
      squares 14, 15, 16, 21
    percentage by years, prior to 1906 11
    plant conditions most favorable 15–17
Peach curculio. (See *Conotrachelus nenuphar*.)

Page.

Pediculoides ventricosus, introduction into Texas an unsuccessful attempt 40–41
  occurrence 30
  parasite of *Anthonomus eugenii* 42–46
    boll weevil (*Anthonomus grandis*). 10–11, 28, 40, 42
Peppers, food plants of *Anthonomus eugenii* 37, 39, 46
Phanerotoma tibialis, parasite of *Anthonomus nigrinus* 44
Phaseolus perennis, food plant of *Apion griseum* 37–45
Phlœosinus graniger, host of *Spathius canadensis* 44
Phoxopteris comptana=*Ancylis comptana* 38
Phytonomus punctatus, host of *Empusa* (*Entomophthora*) *sphærosperma* and *Entomophthora phytonomi* 41
Pissodes strobi, host of *Bracon pissodis* 44
Pityophthorus consimilis, host of *Cerocephala pityophthori* 43
  sp., host of *Rhyssalus pityophthori* 44
Plant conditions most favorable for parasitism of boll weevil 15–17
Plum curculio. (See *Conotrachelus nenuphar.*)
Podapion gallicola, host of *Sigalphus copturi* 43
Polygonum pennsylvanicum, food plant of *Lixus musculus* 25, 34, 36, 45
Porizon conotracheli, parasite of *Conotrachelus nenuphar* 43
Potato-bud weevil. (See *Anthonomus nigrinus.*)
  stalk weevil (see also *Trichobaris trinotata*).
    bibliographic reference 51
Prairie, parasitism of boll weevil 17, 18, 22
Proliferation, factor in control of boll weevil 3
Propagation of boll-weevil parasites artificially, apparatus used, and difficulties. 22–24
  work on parasites of boll weevil 11, 22–27
Prosopis glandulosa, food plant of *Bruchus prosopis* 38
Raspberry, food plant of *Anthonomus signatus* 45
Red-bud, food plant of *Anthonomus signatus* 45
Rhyssalus pityophthori, parasite of *Pityophthorus* sp 44
Rhyssematus lineaticollis, host of *Bracon rhyssemati* 44
Rhynchophora, parasites, list 41–44
Rose, wild, food plant of *Anthonomus signatus* 45
Scolytid, host of *Cerocephala scolytivora* 43
Scymnus in cotton squares 10
Shade, parasitism of boll weevil 17, 18, 22
Sideranthus rubiginosus, food plant of *Brachytarsus alternatus* 32, 47
    Desmoris scapalis 39, 45
Sigalphus canadensis, parasite of *Anthonomus scutellatus* 43
  copturi, hosts, list 43
  curculionis, biological notes 38
    hosts, list 44
    occurrence 29
    parasite of boll weevil (*Anthonomus grandis*) 11, 28, 46
      bud, fruit, pod, and stem weevils 48
      Conotrachelus nenuphar 46
      Trichobaris trinotata 47
  sp., parasite of *Chalcodermus æneus* 44
  zygobaridis, parasite of *Zygobaris xanthoxyli* 44
Smicronyx tychoides, host of *Bracon smicronygis* 44
Solanum carolinense, food plant of *Anthonomus nigrinus* 46
  eleagnifolium, food plant of *Anthonomus æneolus* 46
  rostratum, food plant of *Anthonomus æneolus* 46

Page.

Solanum rostratum, food plant of *Trichobaris texana* 25, 36, 38–47
  occurrence with reference to that of Cerambycobius 49
  spp., occurrence with reference to that of Cerambycobius 49
  torreyi, food plant of *Anthonomus æneolus* 46
Solenopsis geminata, enemy of boll weevil 3, 28
Source work on parasites of boll weevil 11, 41–50
Spathius canadensis, hosts, list 44
Sphenophorus parvulus, host of *Myiophasia ænea* 40, 42
  robustus, host of *Myiophasia robusta* 42
Sporotrichum globuliferum, fungous enemy of *Epicærus imbricatus* 41
Squares, fallen, percentage of parasitism of boll weevil 14, 15, 16, 21
  hanging, percentage of parasitism of boll weevil 14, 15, 16, 21
  percentage of parasitism of boll weevil in 1905 13
Strawberry, food plant of *Anthonomus signatus* 45
  leaf-roller. (See *Ancytis comptana*.)
  weevil (see also *Anthonomus signatus*).
    bibliographic reference 51
Sunlight and dryness, favorable to parasitism of boll weevil 22
Sun, parasitism of boll weevil 17, 18, 22
Tachinids, conditions favorable to parasitism of boll weevil 22
Tetrastichus sp., parasite of *Orthoris crotchii* 43
Tomicus pini, host of *Bracon* sp 44
  sp., host of *Spathius canadensis* 44
Trichacis rufipes, parasite of *Balaninus nasicus* (?) 42
Trichobaris texana, biological notes 47
  breeding period 49
  host of *Cerambycobius cyaniceps* 25, 36, 42
  in *Solanum rostratum* 25, 36
  trinotata, host of *Sigalphus curculionis* 38, 44, 47
    in *Solanum rostratum* 38
Tyloderma foveolatum, biological notes 47
  breeding period 49
  host of *Cerambycobius cyaniceps* 36, 42
    Eurytoma tylodermatis 34, 42
    Neocatolaccus tylodermæ 43
  in *Onagra biennis* 34, 36
  fragariæ, host of *Bracon analcidis* 44
Tyroglyphus breviceps, parasite of *Anthonomus eugenii* 42
  boll weevil (*Anthonomus grandis*) .. 11, 28, 30, 41, 42
Urosigalphus anthonomi, biological notes 38
  occurrence 29
  parasite of boll weevil (*Anthonomus grandis*) 11, 28, 44
  armatus, parasite of Balaninus 38, 44
    Conotrachelus spp 44
  bruchi, parasite of *Bruchus prosopis* 38, 44
  (*robustus*). (See *Urosigalphus anthonomi*.)
  schwarzi, occurrence 29
    parasite of boll weevil (*Anthonomus grandis*) 28, 38, 44
Vipio belfragei, parasite of *Lixus scrobicollis* 44
Weevils contributing parasites of boll weevil, biologies 44–48
Winter temperatures, factor in control of boll weevil 3
Woodland, parasitism of boll weevil 17, 18, 22